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Annular Core Pulse Reactor (ACPR): Experimenter's Manual

L. L. Bonzon, F. M. Morris, F. V. Thome

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ANNULAR CORE PULSE REACTOR (ACPR): EXPERIMENTER'S MANUAL

L. L. Bonzon
F. M. Morris
F. V. Thome
Reactor Source Applications Division 5221
Sandia Laboratories
Albuquerque, New Mexico 87115

ABSTRACT

This report summarizes ACPR operational characteristics and procedures for experimenters. Emphasis is on the user's needs regarding facility access and in estimating total exposure to the experiment. This document replaces Sandia Laboratories publication SC-M-68-454, "Annular Core Pulse Reactor Experimenter's Manual" as the applicable manual for ACPR.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

ANNULAR CORE PULSE REACTOR (ACPR):
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CHAPTER I

INTRODUCTION

This document is the basic source of information for users of the Annular Core Pulse Reactor (ACPR).[1,2,3] The features and operational characteristics of the facility are described and procedures for preplanning of radiation-effects experiments are defined. The facility is designed for experiments that require intense pulses of neutrons and gamma rays, or lower rates at continuous levels.

ACPR is owned by the Atomic Energy Commission (AEC) and operated by Sandia Laboratories at Albuquerque, New Mexico. Its principal use is in a continuing program of fundamental and applied research in radiation effects. As such, the reactor is available to Sandia Laboratories and to the Atomic Energy Commission and Department of Defense agencies and contractors.

Information not included in this report may be obtained by addressing the ACPR Reactor Supervisor, Sandia Laboratories, Albuquerque, New Mexico, 87115.

CHAPTER II

FACILITY

Location

ACPR is located on Kirtland Air Force Base East, in Sandia Laboratories' Technical Area V (TA-V), outside the northeast corner of TA-III; these areas are about 6 kilometers south of the main laboratory complex in TA-I. Figure 1 shows the location of the reactor complex with respect to other areas of Albuquerque and Kirtland AFB East.

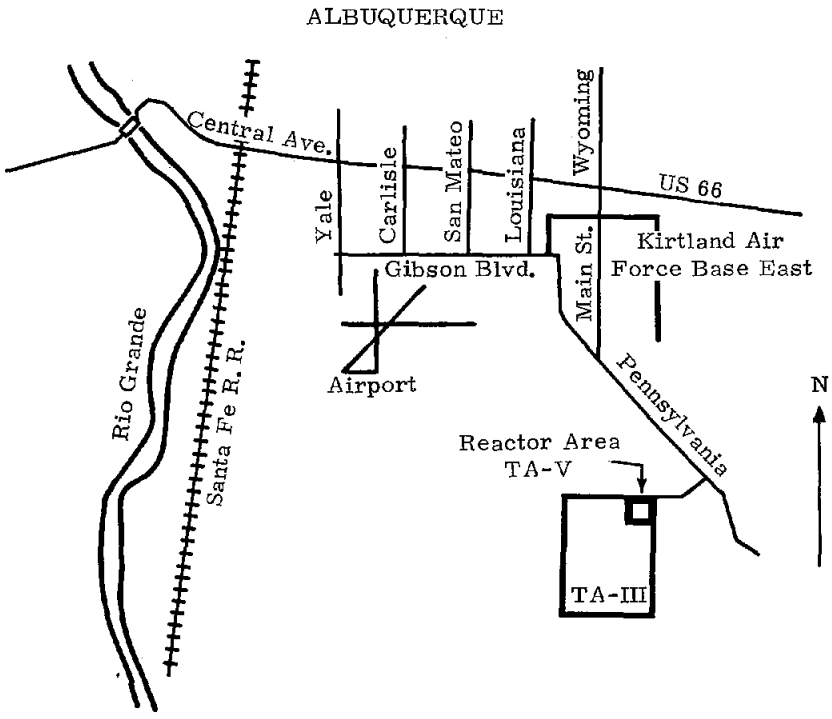
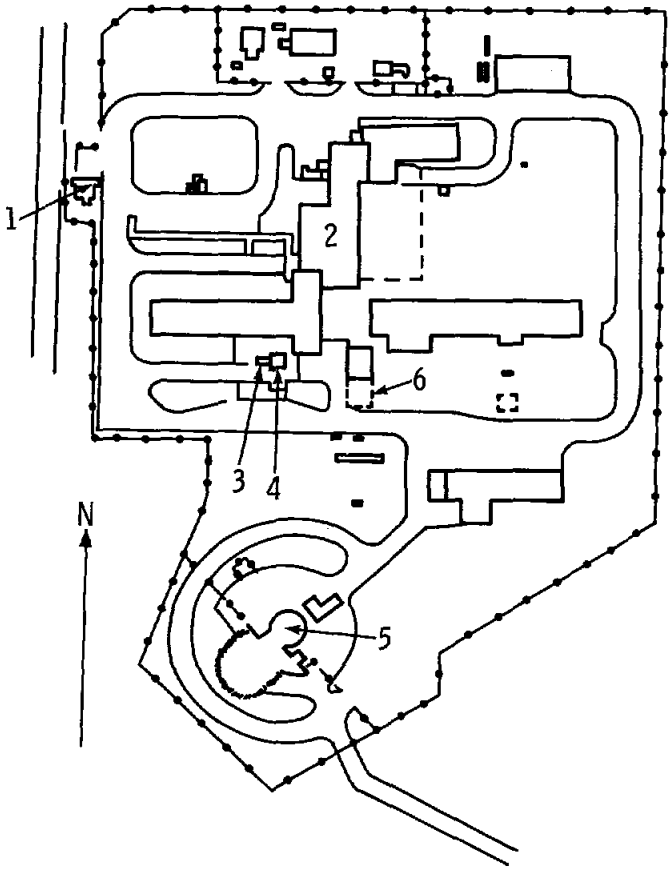


Figure 1. Location of TA-V

Figure 2 shows the location of buildings in TA-V. Only buildings directly concerned with ACPR are discussed here.



1. C5 Guard Gate, Visitor Access
2. Information (Bldg 6580)
3. Annular Core Pulse Reactor, ACPR (Bldg 6588)
4. Gamma Irradiation Facility (GIF) (Bldg 6588)
5. Sandia Pulsed Reactors, SPR II/III (Bldg 6590)
6. Nuclear Counting Laboratory (Bldg 6594)

Figure 2. TA-V

Reactor Building

The ACPR is housed in the portion of Building 6588 called the High Bay; this building is part of a larger complex that includes two other major structures, Buildings 6580 and 6581. Building 6588 contains the High Bay, building utilities, several small laboratories, a computer complex, and numerous offices (Fig. 3). The High Bay is physically separated from the other spaces by a common continuous concrete-block wall that forms one side of the High Bay. Access to the High Bay is provided through four doorways, three for personnel and one for equipment, which may be locked. Passageways lead from two of the personnel doors into the common hallway for Building 6588. The third personnel door permits access into the mechanical equipment room, which contains various water-control, heating, and ventilation equipment. The equipment access door is a standard 3.6 x 3.6 m motor-driven lift-type metal door located in the west wall of the High Bay. One portion of the High Bay contains the Gamma Irradiation Facility (GIF).[4]

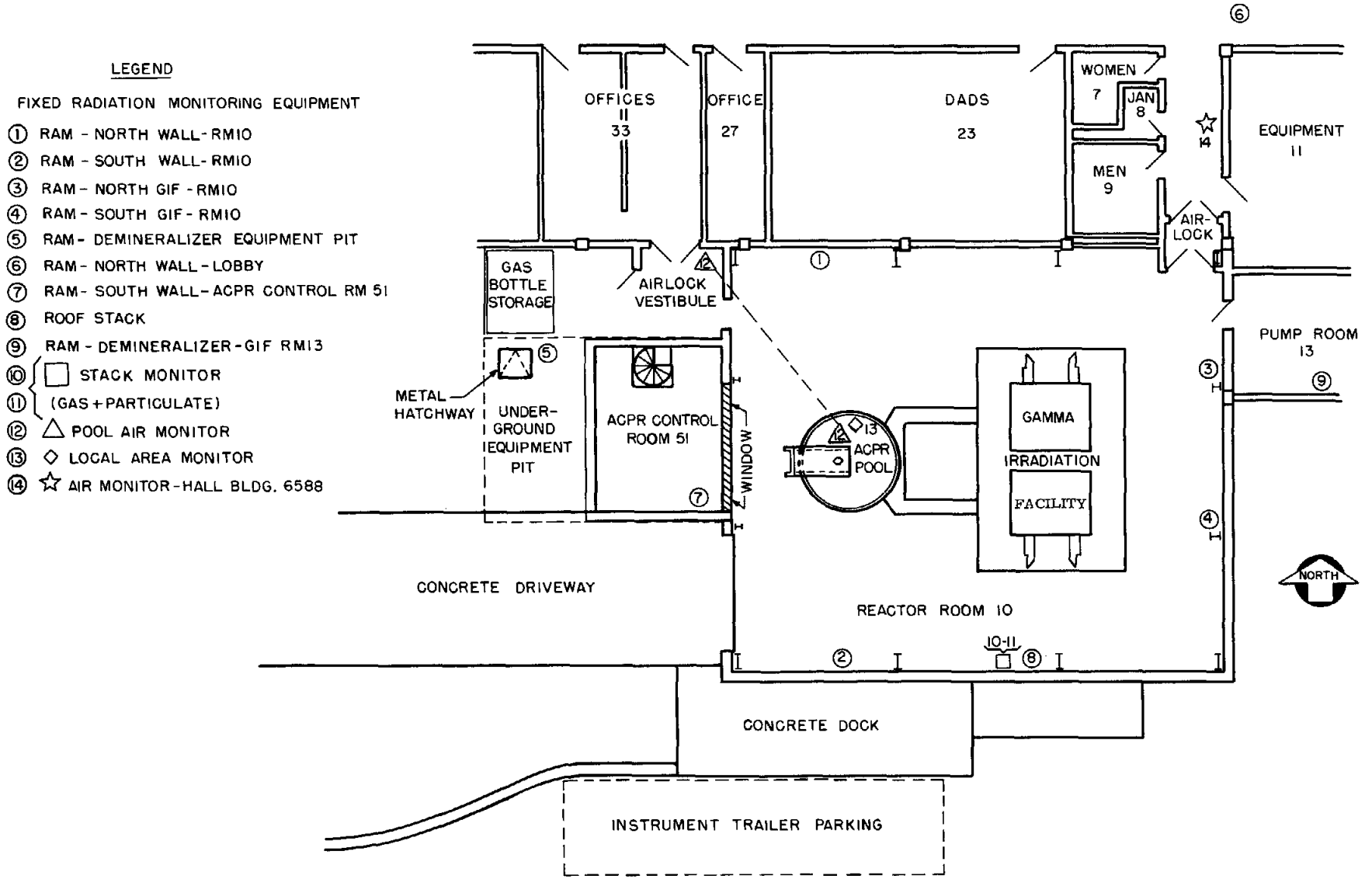


Figure 3. Floor Plan Adjacent to the ACPR

Heavy equipment in the reactor room is normally handled by means of an overhead crane. This crane is equipped with a 133-kN (15-ton) hoist and a 27-kN (3-ton) hoist mounted on a traveling bridge. Complete coverage of the reactor room is provided by the crane.

The reactor room is 13.6 meters wide by 15.8 meters long by 9.5 meters high. The floor is a uniform thickness of 20.3-cm reinforced concrete. Walls are of standard 30.5-cm (12-inch) concrete blocks set between steel support columns. The roof consists of a 20-gauge metal deck supported on steel trusses and covered with a multiple layer of insulation and asphalt sealer 7.6 cm thick.

The ACPR control room is a self-contained room adjacent to the High Bay. Large heavy Lexan windows in the High Bay west wall permit control-room personnel to observe all reactor operations and activities in the High Bay. The control-room ventilation system is completely separate from the High Bay ventilation system. The latter consists of two distinct parts; a supply system and an exhaust system. The supply system provides conditioned air at a rate of about 1.9 m^3/sec and the exhaust system extracts air at a rate of about 4.7 m^3/sec. The difference is made up from in-leakage to assure that the High Bay remains at a negative pressure with respect to all other zones. A supplemental exhaust system in the reactor experiment tube purges the tube of radioisotopes (particularly Argon-41) and prevents radiation buildup. This system exhausts directly into the main High Bay exhaust system through a filter. The High Bay exhaust discharges through a plenum and stack mounted on the roof.

Experimenter Areas

The floor area surrounding the ACPR pool (Fig. 3) is available for experimenters and special equipment. The area also houses semipermanently installed analysis and recording equipment. Typical of this equipment are tape recorders, oscilloscopes, power supplies, and amplifiers. An on-line computer system, using an EMR-6130 computer (the DADS system), can also be made available for data acquisition and display. In addition, an instrument trailer parking area is located just south of the reactor building (Fig. 3), with cable trenches connecting the parking site to the reactor area. Arrangements can be made for the use of the other data-collecting instrumentation.

CHAPTER III

REACTOR DESCRIPTION

Physical Description[5]

The ACPR (Fig. 4) is a TRIGA-type reactor utilizing stainless-steel-clad uranium/zirconium-hydride (ZrH) fuel elements, but with a dry experiment cavity 23 cm in diameter occupying the central region of the core. The core structure is at the bottom of a stainless-steel-lined water-filled tank 3.05 m in diameter and 8.5 m deep. The top of the core is 7.0 m below the water surface.

The core contains fuel-moderator elements (Fig. 5) in which a ZrH moderator is homogeneously combined with enriched uranium fuel. The active section of this fuel-moderator element is 38.1 cm in length by 3.56 cm in diameter and contains 12 weight percent uranium and 88 weight percent zirconium hydride. The 12 weight percent uranium is enriched to 20 percent in ^{235}U and the hydrogen-to-zirconium atom ratio of the ZrH moderator material is 1.625 to 1. Graphite cylinders 8.8 cm in length by 3.56 cm in diameter act as top and bottom reflectors.

The active fuel section and the top and bottom graphite cylinders are contained in a Type 304 stainless-steel cladding 0.5 mm thick. The clad is provided with dimples that act as spacers to ensure a thermal gap between the fuel meat and the clad. The approximate overall weight of the element is 3.4 kg, and the ^{235}U content is about 54 grams.

The fuel elements are arranged on a triangular spacing grid; the operational core loading of the reactor comprises 141 to 160 fuel moderator elements, 6 fuel-followed control rods, and 3 poison-air-followed transient rods (Fig. 6).

Six motor-driven control rods govern reactor power during delayed critical operations. The rods are of the fuel-follower type wherein the reactivity effect of removing the poison as the rod is withdrawn is augmented by the simultaneous insertion of the fuel-follower section. These control rods pass through and are guided by holes in the top and bottom grid plates. The control rods have a stroke of about 38.1 cm.

The adjustable transient rod on the ACPR is actuated by an electro-pneumatic system. The mechanical drive system permits the adjustable transient rod to be used in the steady-state as well as the pulse mode of operation. In the pulse mode the adjustable drive system is used to adjust reactivity so that pulses of any size may be obtained up to the maximum reactivity worth of the transient rod system. The adjustable transient rod has a stroke of 38.1 cm and can be pneumatically removed from the core in about 150 msec.

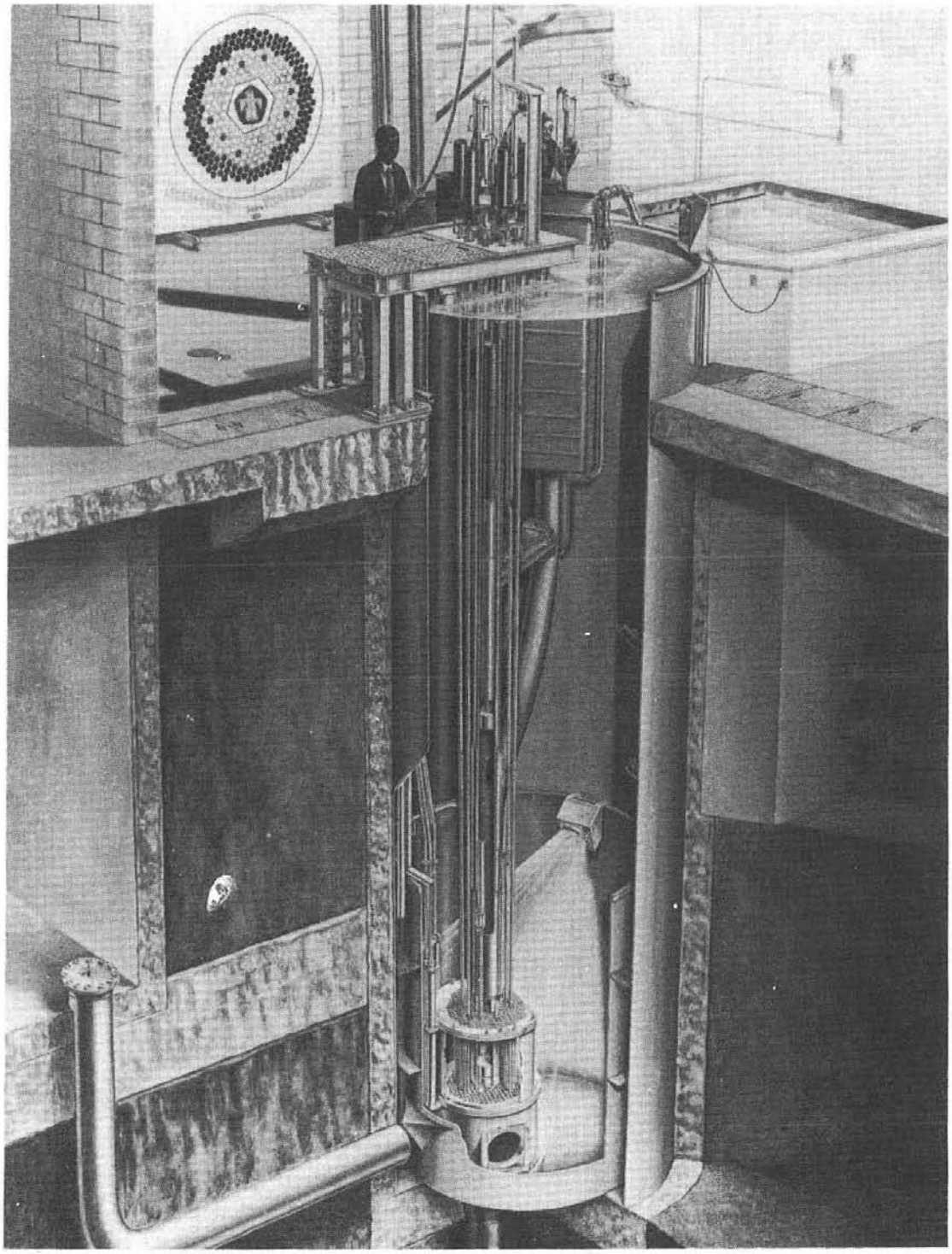


Figure 4a. ACPR Facility

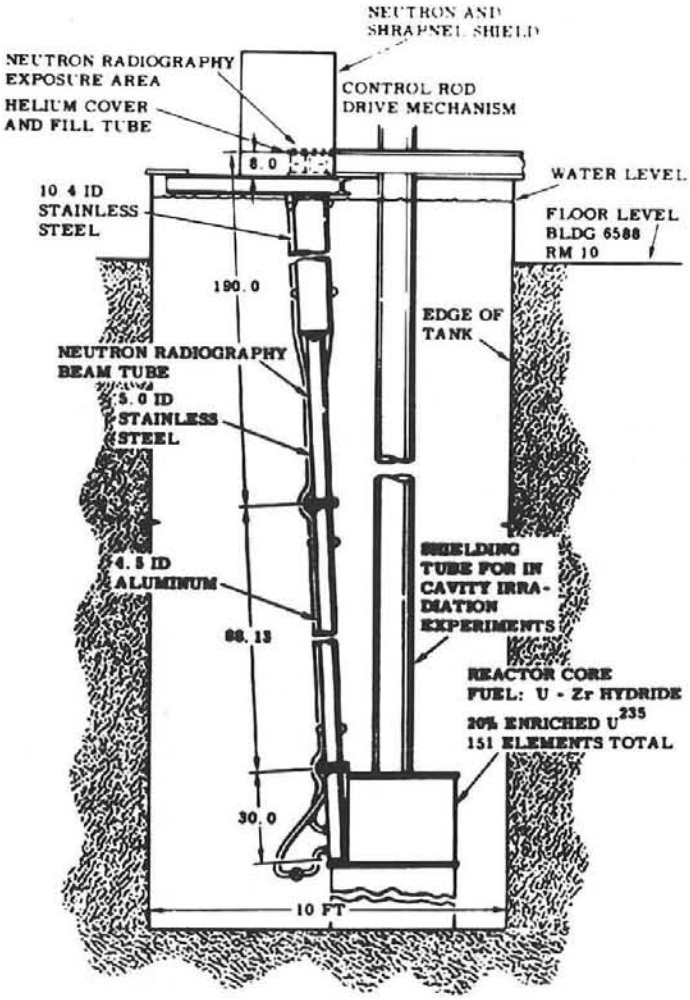


Figure 4b

ACPR Neutron Radiography Facility;
(Dimensions in inches except as noted.)

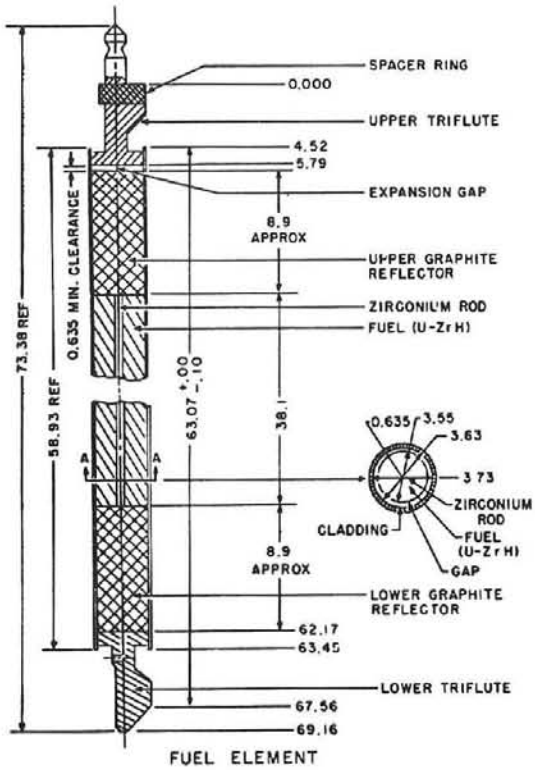


Figure 5

ACPR Fuel Element; Dimensions
in Centimeters

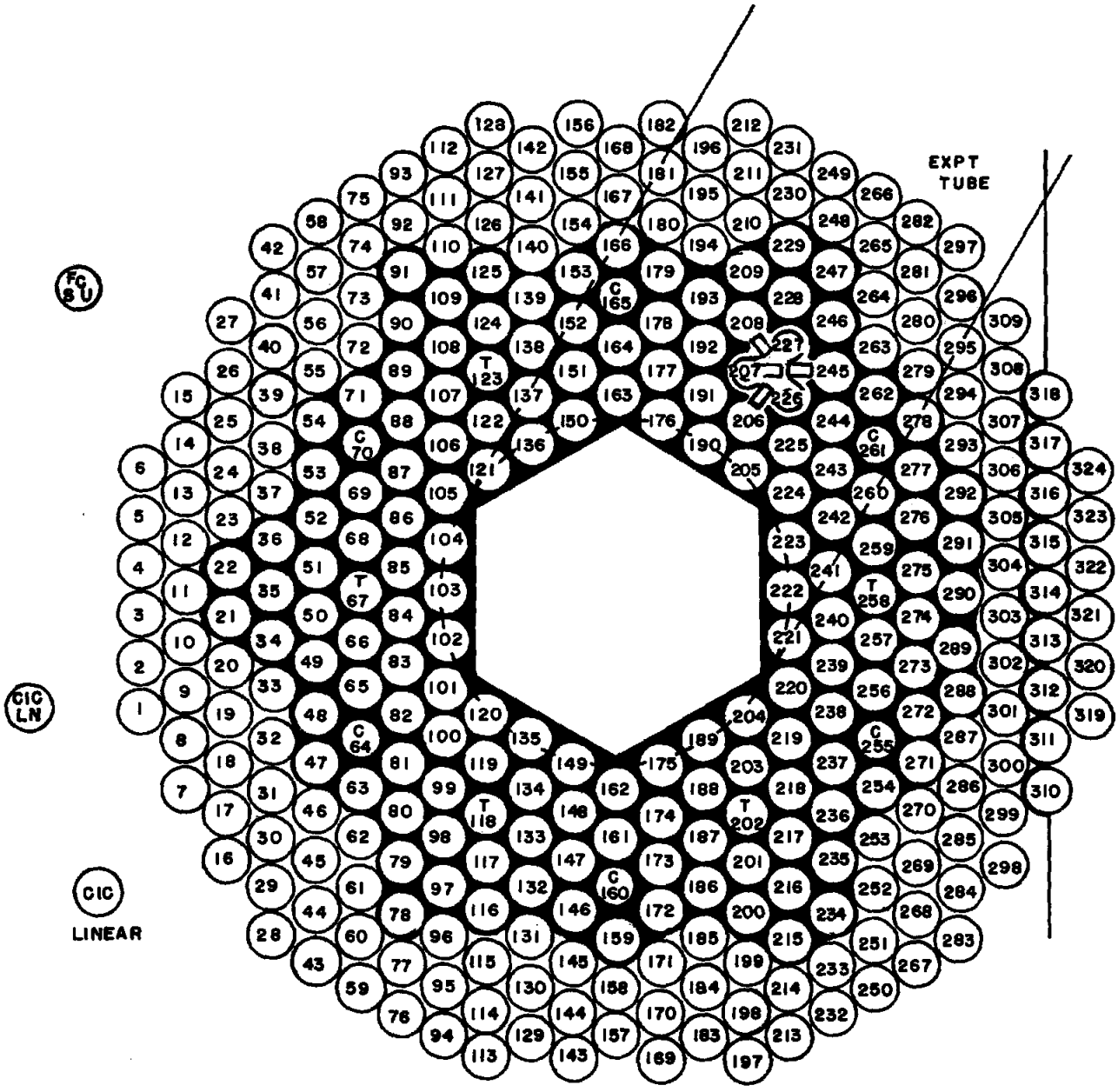


Figure 6. ACPR 151 Fuel-Element Core

The fast transient-rod system is designed to meet the needs of higher-power pulse yields by achieving a high rate (~ $100/sec) of reactivity insertion. This is done by providing a double-length poison section in each rod with an air follower. The first 38.1 cm of travel occurs at a higher rate than for the adjustable transient rod. The time required for the reactivity stroke of 38.1 cm is 40 to 50 msec, depending on pressure settings.

Feature Description

The ACPR is used in a continuing program of fundamental and applied research in radiation effects. Its design is such that a wide variety of experiments can be accommodated easily; it significantly extends earlier capabilities for neutron irradiation.

The main feature of the reactor is the 23-cm (effective) diameter dry experiment cavity that occupies the center region of the reactor core. In this large, hexagonal, dry cavity, experiments can be exposed to total neutron fluence in excess of 3×10^{15} n/cm^2 in a single pulse. The center of the 30.5-cm-high cavity coincides with the center of the fuel in the core. The cavity is bounded on the bottom by a 13-cm-thick stainless-steel reflector and on the top by an aluminum reflector 2.54 cm-thick. If an experiment is longer than 30.5 cm, the lower and upper reflectors may be removed to accommodate it.

Access to the central irradiation cavity is provided by a vertical loading tube and an offset loading tube that join in a "Y" fitting about 2.4 meters above the top of the core (Fig. 4). Both tubes are fabricated from stainless-steel pipes. The inside of the pipe provides adequate clearance for passage of an experiment ~23 cm in diameter by ~46 cm in length through the curved sections.

A facility for post-irradiation experiment storage is located in the upper section of the offset loading tube. Experiments may be stored in this section until sufficient radioactive decay has taken place to allow convenient handling and removal. The section provides space to store two experiments at a depth of more than 1.5 meters below water level and 1 meter below floor level. Shielding is provided by lead slabs over the storage position.

Two other notable features are associated with the experiment capability at ACPR. The first is the neutron radiography facility; the collimator tube extends from the flattened side of the core to a blast and radiation shield (~1 meter on a side) that covers the upper end of the tube adjacent to the reactor bridge. Containers of D_2O surround this tube at its base near the core to aid in neutron thermalization. Experiments can also be located in this tube to within ~0.6 cm of the core; experiments must be smaller than 36 cm square by 45 cm high.

Secondly, the flexo-rabbit (pneumatic transfer) system allows rapid sample transfer into and out of the core. The 4.5-m aluminum irradiation endpiece is designed to fit directly into any fuel element position in the core grid plate; experiments must be smaller than 1.9 cm in diameter by 5 cm long.

Complete discussion of all experiment capabilities is included in Chapter V.

Safety Features

In the pulse mode, the energy released for a reactivity insertion of $4.40 is ~100 MW-sec with a reactor period of 1.3 msec; the fuel reaches a maximum adiabatic temperature of 870° C with an average core temperature of about 550° C.

The principal safety feature of the ACPR is the large prompt negative temperature coefficient of reactivity. This temperature coefficient arises primarily from a change in the disadvantage factor resulting from the heating of the uranium/zirconium-hydride fuel-moderator elements. The coefficient is prompt because the fuel is intimately mixed with a large portion of moderator; thus, the fuel and solid moderator temperatures rise simultaneously.

The basic physical processes that occur when the fuel-moderator elements are heated can be described as follows: the rise in temperature of the hydride increases the probability that a thermal neutron in the fuel element will gain energy from an excited state of an oscillating hydrogen atom in the lattice. As the neutrons gain energy from the ZrH their mean free path is increased appreciably. Thus, the probability of escape from the fuel element before capture is increased. In the water the neutrons are rapidly re-thermalized so that the capture and escape probabilities are relatively insensitive to the energy with which the neutron enters the water. The heating of the moderator mixed with the fuel thus causes the spectrum to harden more in the fuel than in the water. As a result, there is a temperature-dependent disadvantage factor for the unit cell in the core which decreases the ratio of absorptions in the fuel to total-cell absorptions as fuel-element temperature is increased. This change in disadvantage factor brings about a shift in the core neutron balance, giving a loss of reactivity, and is termed the cell effect.

Although the cell effect is the predominant prompt-shutdown mechanism for the ACPR, other effects such as Doppler broadening of ^{238}U resonances, leakage, and irregularities in the fuel lattice due to control rods, also contribute to the prompt-shutdown process as the fuel is heated.

In addition to the inherent prompt-shutdown process, certain protective features[2] are built into the reactor control system that will automatically limit the power and temperature levels at which the reactor can be operated, or which will prevent operation (i.e., shut down the reactor) if certain conditions have not been met.

Modes of Operation

The ACPR is capable of steady-state operation at 300 kW for extended periods (authorization for 600-kW operation is expected during 1974). In the pulse mode, the peak power is ~14,000 MW with a total energy release of ~ 100 MW-sec. Typical ACPR operational characteristics are shown in Table I. Detailed information on radiation levels and rates is given in Chapter IV.

TABLE I

ACPR Operational Characteristics
(Cavity Horizontal and Vertical Centerline, Free-Field)

Pulse Operations:	
Reactivity Inserted	$4.40
Peak Power	14000 MW
Pulse Width (FWHM)	4.7 msec
Reactor Period	1.3 msec
Maximum (Recorded) Fuel Temperature	750° C
Energy Release	~100 MW-sec
Neutron Dose:	
> 10 keV	1.7×10^{15} n/cm^2
Maximum rate (> 10 keV)	3.6×10^{17} n/cm^2-sec
All Energies	3.4×10^{15} n/cm^2
Thermal (< 0.4 eV)	7.8×10^{14} n/cm^2
Gamma Dose:	
Total Dose	10^6 rads (H_2O)
Maximum Rate	2.1×10^8 rads (H_2O)/sec
Characteristics of Steady-State Operation:*	
Power	300 kW
Neutron Flux (> 10 keV)	5×10^{12} n/cm^2-sec
Neutron Flux (All Energies)	1×10^{13} n/cm^2-sec
Gamma Dose Rate	3300 rads (H_2O)/sec

*Approval for 600 kW steady-state operation is expected in 1974; all table entries will double for 600 kW operation.

CHAPTER IV

RADIATION LEVELS AND RATES

General

Various neutron and gamma measurements have been made in the experiment cavity and in the core itself. In general, these measurements were "free-field"; i. e. , there were no spectrum-perturbing experiments in, or near, the reactor during the measurements. Experiments change the spectrum and flux distributions, the variation depending on the kind and amount of material used; the following data therefore are to be used only as a guide. It is recommended that when precise environment data are required, such measurements be made concurrent with the experiment.

The errors and uncertainties associated with these data have been analyzed, establishing that the uncertainties with any one measurement point are at worst ±10 percent. This uncertainty is inherent in any spectral or fluence measurement because of contributing factors relating to detector calibration and positioning, cross-section information, signal measurements, and foil counting. The uncertainties in the reported data are typical and representative of the current state-of-the-art.

Pulse Characteristics

Pulse width varies inversely with pulse yield; the larger the temperature excursion, the narrower the pulse. Figures 7 through 14 detail the pulse characteristics in terms of pulse yield, pulse width, initial period, and initial prompt reactivity for a bare cavity at the cavity centerline. Immediately following the pulse the reactor power exhibits a ~10-MW "tail" (Fig. 11), so that only 75 to 85 percent of the total energy is associated with the prompt pulse (Fig. 12). Pulses are predictable to within ~ 5 percent.

Pulse repetition rate is determined by the repeatability required between the first and subsequent pulses. Figures 15 and 16 summarize the pulse characteristics for the repetitive pulsing mode of operation. As shown, maximum pulses can be generated approximately every 30 minutes; at reduced levels of fluence, power, etc. , pulses may be generated as rapidly as every 4 minutes.

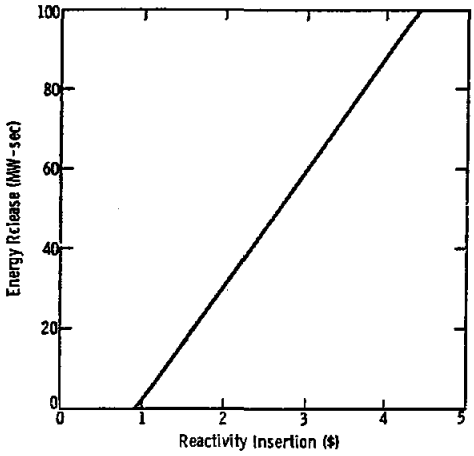


Figure 7. Pulse Energy Release Versus Initial Reactivity Insertion

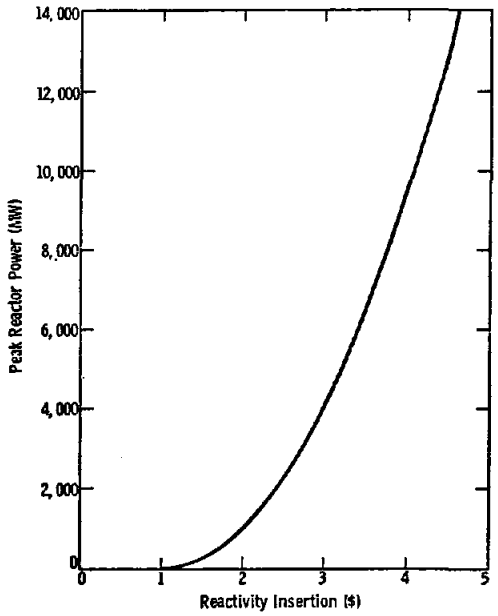


Figure 8. Peak Pulse Reactor Power Versus Initial Reactivity Insertion

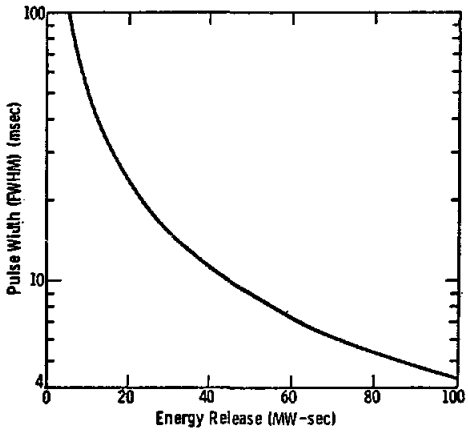


Figure 9. Pulse Width at Half Maximum Power Versus Pulse Energy Release

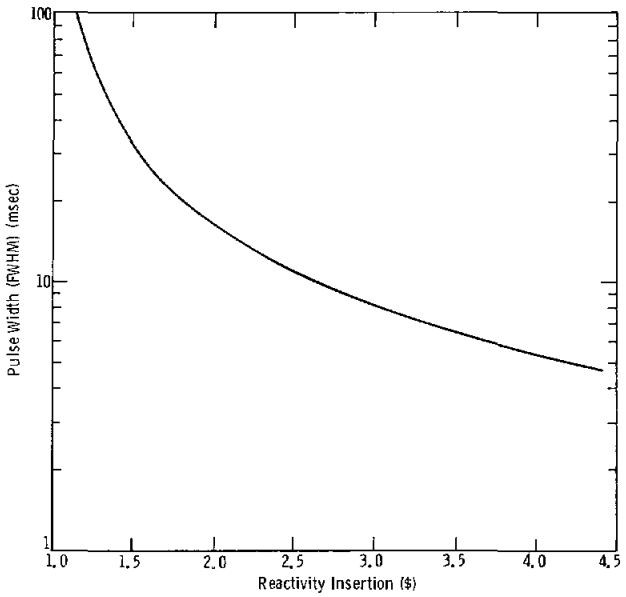


Figure 10. Pulse Width Versus Initial Reactivity Insertion

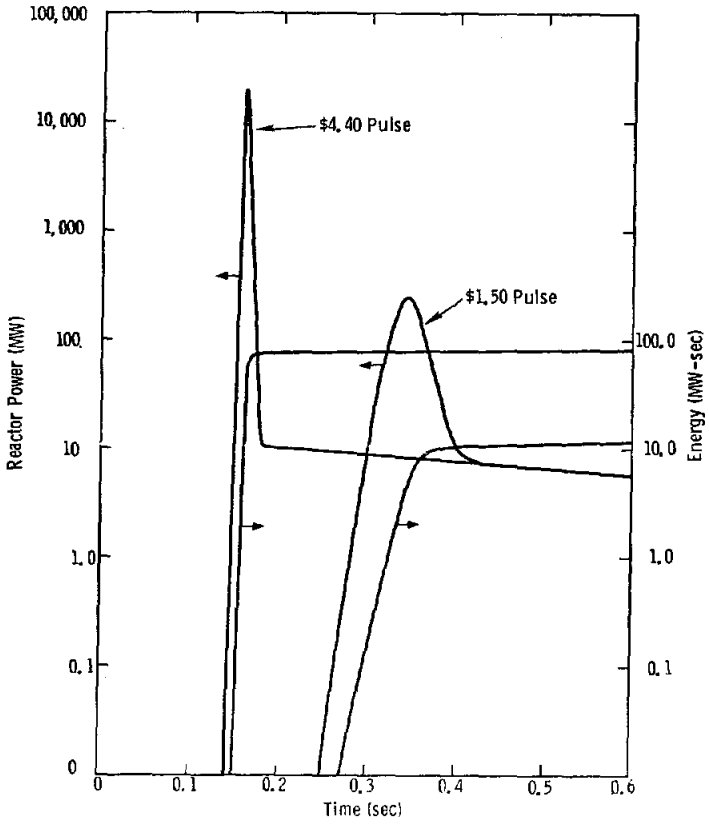


Figure 11. Typical Pulse Shapes Showing the 10-MW "Tail" and the Corresponding Pulse Integrals. Time "0" is the Start of Reactivity Insertion.

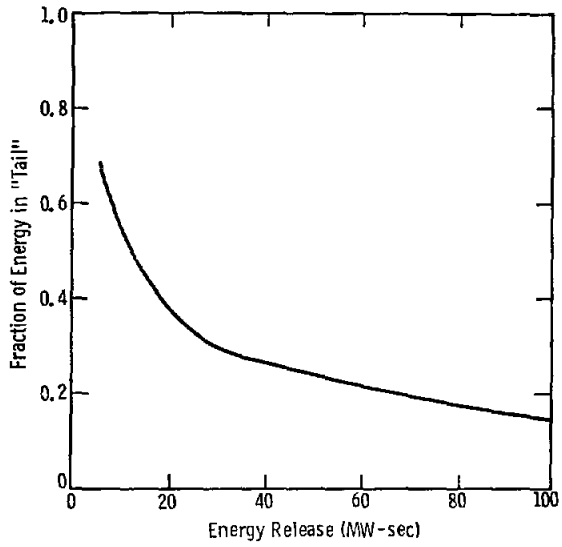


Figure 12. Fraction of Energy in the Pulse "Tail" Versus Total Pulse Energy Release

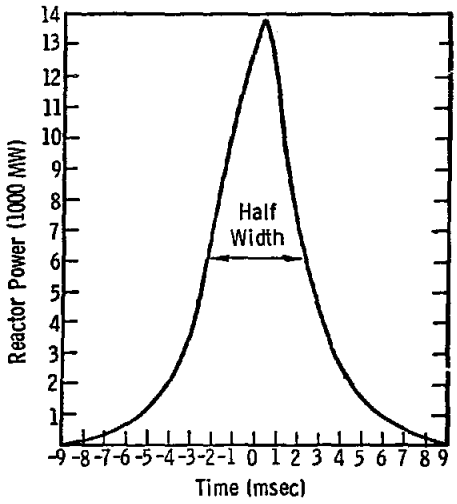


Figure 13. Typical Pulse Shape

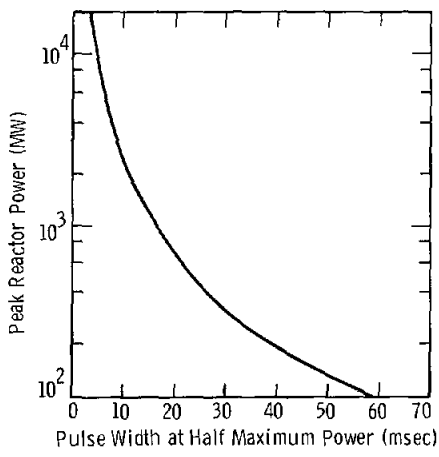


Figure 14. Peak Power Versus Pulse Half Width

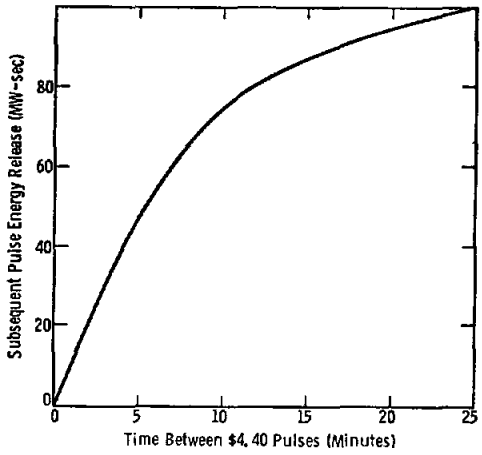


Figure 15. Energy Release of Next $4.40 Pulse as a Function of Time Between Pulses

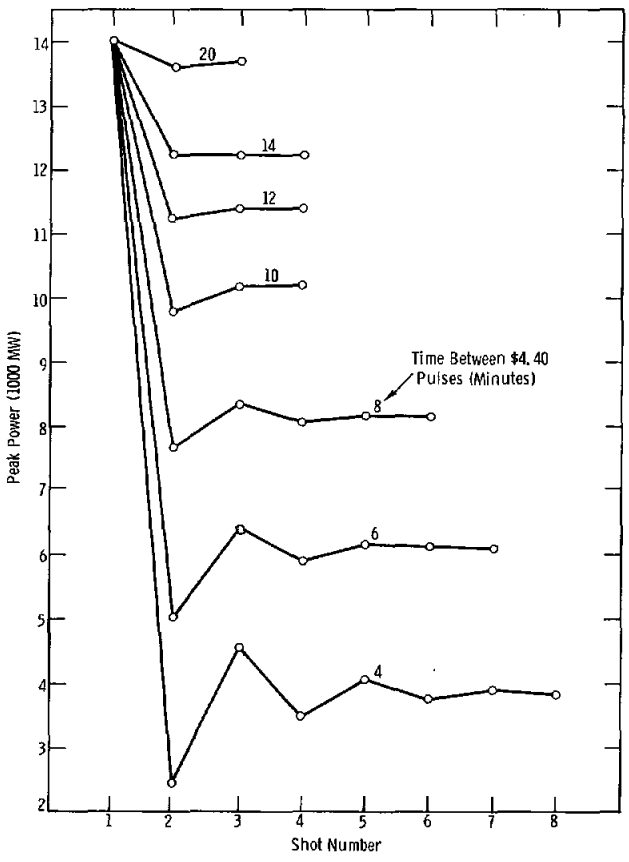


Figure 16. Peak Power of Repetitive Pulses With Wait Time Between Pulses as a Parameter

Neutron Energy Spectra

Neutron energy spectra and fluences have been measured using activation foils[3,6,7] requiring data unfolding via computer codes. Figures 17, 18, and 19 summarize these spectrum measurements. Table II summarizes the differential and integral cavity neutron energy spectrum in 16-group format. Table III shows a finer group structure of the bare-cavity spectrum from Figure 19.

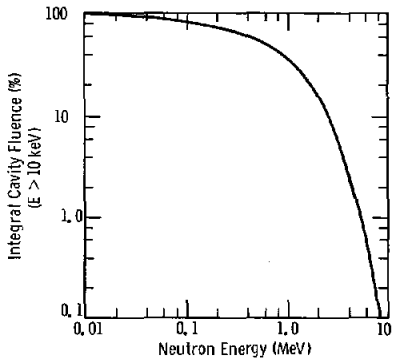


Figure 17. Integral Neutron Spectrum (Ref 3)

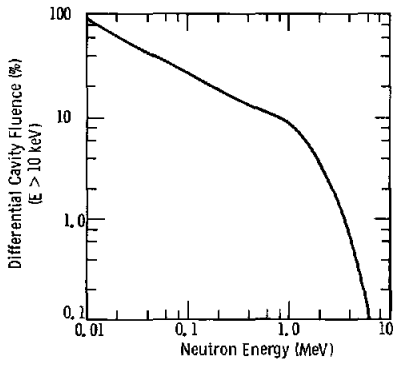


Figure 18. Differential Neutron Spectrum (Ref 3)

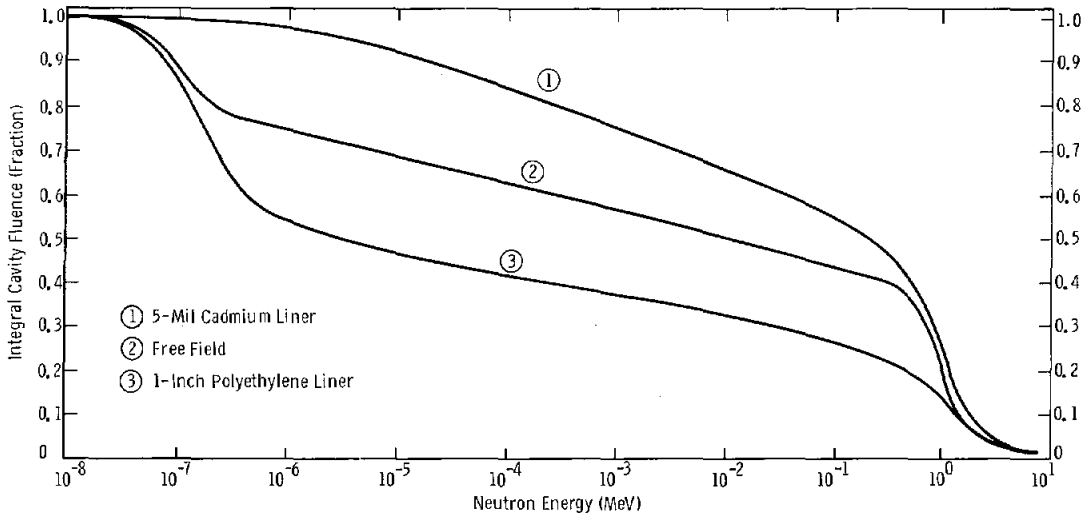


Figure 19. Integral Cavity Fluence for all Neutron Energies, Showing the Effects of Spectral Modifications (Ref 7)

TABLE II

ACPR Cavity Spectra[6,7]

Group	Lower Limit Energy of Group	Free-Field Normalized Differential Spectrum	Normalized Integral Spectrum*		
			Free-Field	2.54 cm Polyethylene	0.0127 cm Cadmium
1	3 MeV	0.033	0.033	0.03	0.05
2	1.4	0.084	0.117	0.10	0.14
3	0.9	0.113	0.230	0.15	0.28
4	0.4	0.139	0.369	0.21	0.44
5	0.1	0.071	0.440	0.26	0.55
6	17 keV	0.050	0.490	0.31	0.64
7	3	0.047	0.537	0.35	0.71
8	0.55	0.044	0.581	0.39	0.77
9	100 eV	0.041	0.622	0.42	0.84
10	30	0.033	0.655	0.44	0.88
11	10	0.029	0.684	0.47	0.92
12	3	0.036	0.720	0.51	0.95
13	1	0.029	0.749	0.54	0.97
14	0.4	0.024	0.773	0.61	0.98
15	0.1	0.122	0.895	0.86	0.99
16	Thermal	0.107	1.0	1.0	1.0

*From Figure 19

TABLE III*

ACPR Bare Cavity Spectrum[6,7]

Energy		Percent of Neutrons Above Indicated Energy		Energy		Percent of Neutrons Above Indicated Energy	
		Over All Energies	Energies > 10 keV			Over All Energies	Energies > 10 keV
MeV	eV	(%)	(%)	MeV	eV	(%)	(%)
1.0×10^{-8}	0.01	100.0	--	1.0×10^{-3}	1 keV	56.5	--
2.0		99.7	--	2.0		54.6	--
4.0		98.0	--	4.0		52.7	--
6.0		95.3	--	7.0		51.2	--
8.0		92.3	--	1.0×10^{-2}	10 keV	50.3	100.0
1.0×10^{-7}	0.1	89.3	--	2.0		48.4	96.2
2.0		80.8	--	4.0		46.5	92.4
4.0		77.1	--	7.0		45.0	89.4
6.0		76.1	--	1.0×10^{-1}	100 keV	44.0	87.5
8.0		75.4	--	2.0		41.6	82.8
1.0×10^{-6}	1.0	74.8	--	4.0		36.9	73.3
2.0		72.9	--	7.0		28.8	57.2
4.0		70.9	--	1.0×10^{0}	1 MeV	20.1	39.9
6.0		69.7	--	1.5		9.64	19.2
8.0		68.9	--	2.0		5.68	11.3
1.0×10^{-5}	10.0	68.3	--	3.0		3.34	6.63
2.0		66.4	--	4.0		2.29	4.54
4.0		64.5	--	5.0		1.61	3.21
7.0		63.0	--	6.0		1.13	2.25
1.0×10^{-4}	100.0	62.2	--	7.0		0.75	1.48
2.0		60.7	--	8.0		0.46	0.90
3.0		59.7	--	9.0		0.23	0.45
4.0		58.9	--	10.0		0.07	0.13
6.0		57.9	--				
8.0		57.1	--				

*From Figure 19

Polyethylene Filter Spectrum Modifications

The neutron energy spectrum can be modified, thermalized, and/or filtered by the addition of certain materials around the experiment. Figure 19 shows two integral measurements[6,7] of spectrum using cadmium and polyethylene liners. Figures 20 and 21 demonstrate the effect of thermalization as a function of polyethylene annulus thickness, as calculated using the one dimensional DTF-IV code.[8] (Additional spectrum modifications are shown in Figs. 31 and 32.)

Figure 20 also includes comparisons with measured values of the thermal fluence and the > 10-keV fluence.[9] All measurements were made with sulfur (> 3 MeV), gold, and cadmium-covered gold in a 30 kW - 200 sec (~ 6 MW - sec) power run at approximately ambient temperatures and are shown in Table IV. The extrapolated maximum pulse values are based on the measured poly/no-poly ratios. Using sulfur measurements to obtain 10-keV fluences is justified since the relative neutron energy spectrum above 10 keV is not affected by the polyethylene liners, as indicated in the DTF-IV calculations and Figure 21.

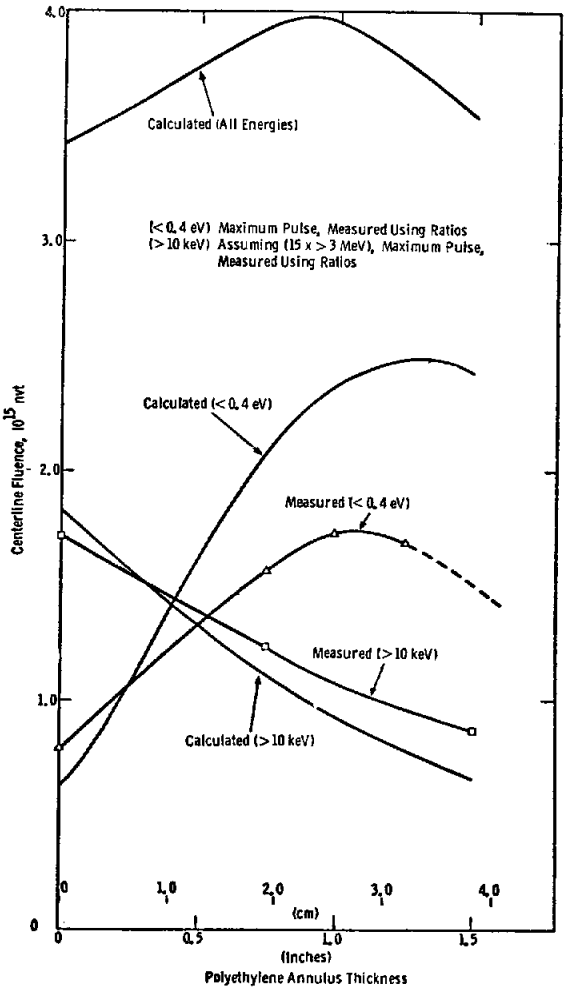


Figure 20. Cavity Fluence for a Maximum Size Pulse Versus Polyethylene Annulus Thickness

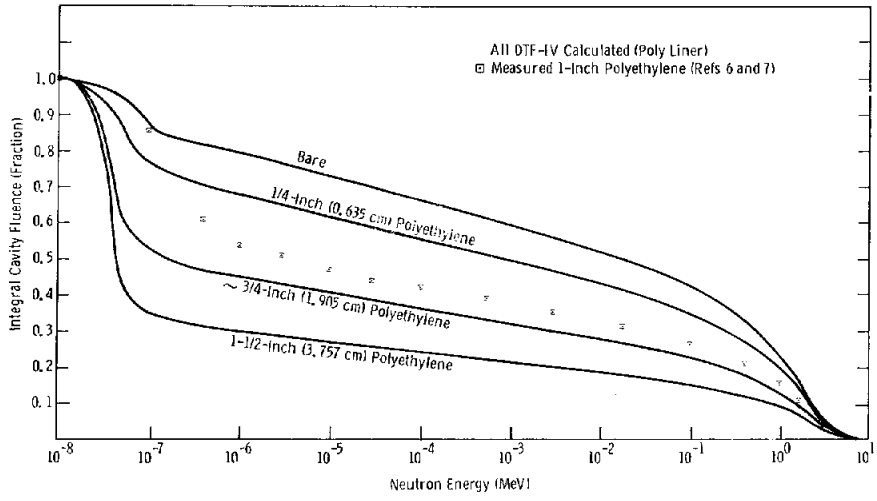


Figure 21. Integral Cavity Fluence Versus Neutron Energy

TABLE IV

Measured Fluence Versus Polyethylene Thickness

Polyethylene Annulus Thickness (in.)	Measured Sulfur (> 3 MeV) (30 kW-200 sec)	Extrapolated Maximum Pulse (> 10 keV) (~100 MW-sec)	Measured Thermal (< 0.4 eV) (30 kW-200 sec)	Extrapolated Maximum Pulse (< 0.4 eV) (~100 MW-sec)
0	7.9×10^{12} n/cm^2	1.7×10^{15} n/cm^{2*}	5.42×10^{13} n/cm^{2**}	7.8×10^{14} n/cm^{2*}
0.75	5.5	1.2	1.08×10^{14} n/cm^2	1.6×10^{15} n/cm^2
1.0	4.9	1.1	1.19	1.7
1.25	4.4	9.5×10^{14} n/cm^2	1.16	1.6
1.50	3.9	8.5	--	--

*Maximum pulse values

**Estimated (not measured) based on Table III values,

22.9 percent of all neutrons below 0.4 eV,

3.34 percent of all neutrons above 3.0 MeV,

and the measured sulfur values from this table of 7.9×10^{12} n/cm^2

$$7.9 \times 10^{12} \text{ n/cm}^2 \left(\frac{22.9\%}{3.34\%}\right) = 5.42 \times 10^{13} \text{ n/cm}^2 \text{ (< 0.4 eV)}$$

The greatest discrepancy between the calculated and measured values in Fig. 20 occurs in the thermal group. The calculated thermal fluence is ~ 40 percent higher than the measured value with a 1-inch polyethylene annulus; the > 10-keV calculated fluence is ~ 10 percent low for the same polyethylene thickness. Additional measurements are required to precisely establish the thermal fluence values.

Neutron Fluence Profiles

Neutron fluence data are quantitatively presented in Figs. 22 through 27 for the bare-cavity maximum-fluence position.

Cavity-Positioned Experiments

Experiments requiring lower neutron and gamma fluences (without sacrificing pulse width) than can be obtained in the cavity may be positioned in the experiment tube. Figure 28 shows relative fluences as a function of distance from the bottom of the cavity. Since the neutron energy spectrum is not expected to be a strong function of cavity position, the relative neutron fluence is valid for most other neutron energies as well. Predictability of doses at any position is within 20 percent.

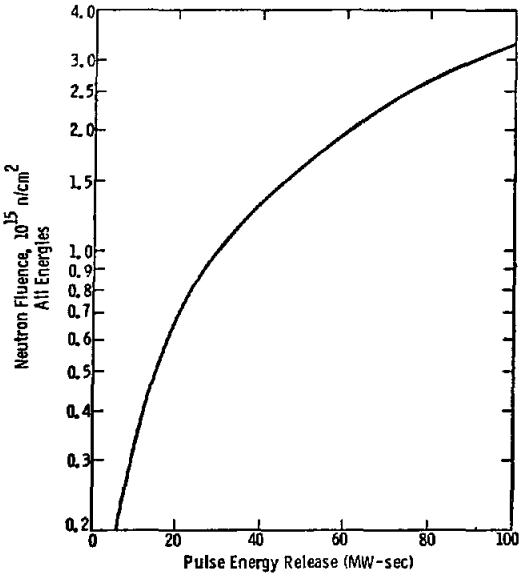


Figure 22. Neutron Fluence (Cavity, Free-Field) as a Function of Pulse Energy Release

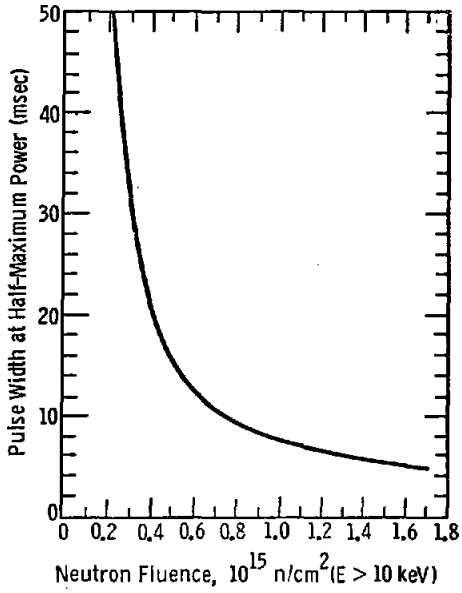
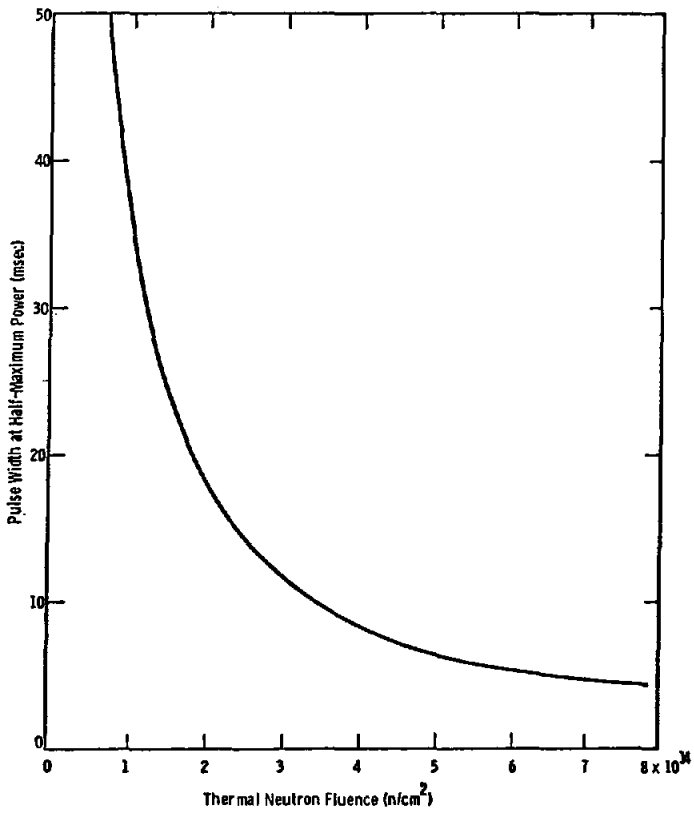


Figure 23. Neutron Fluence in the Experiment Cavity

Figure 24

Thermal Neutron Fluence (< 0.4 eV) in Experiment Cavity (based on 22 9% of total neutrons having energies less than 0.4 eV from Table III)



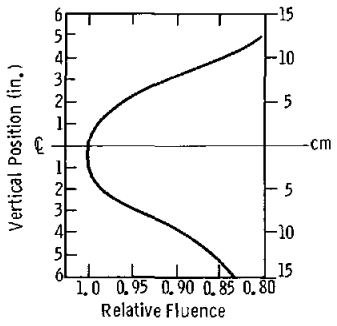


Figure 25. Relative Vertical Fluence in Experiment Cavity

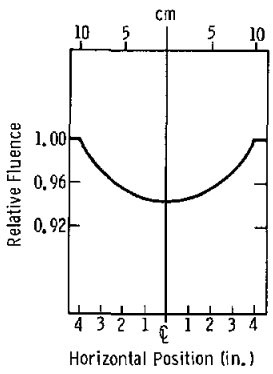


Figure 26. Relative Horizontal Fluence in Experiment Cavity

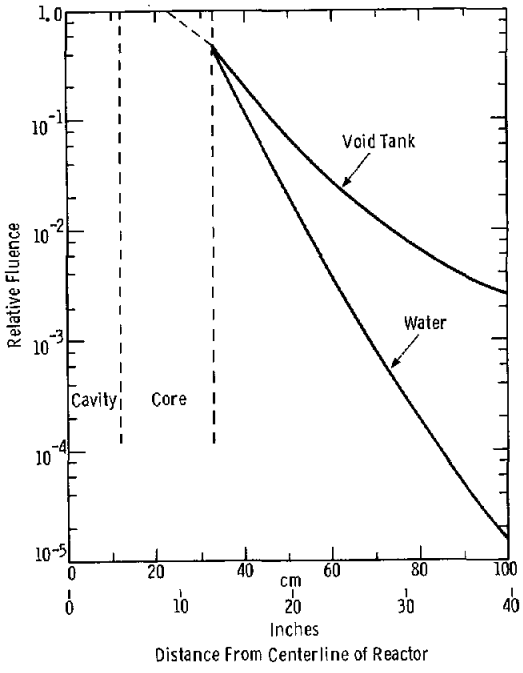


Figure 27. Relative Neutron Fluence (E > 3 MeV) From Reactor Axial Centerline

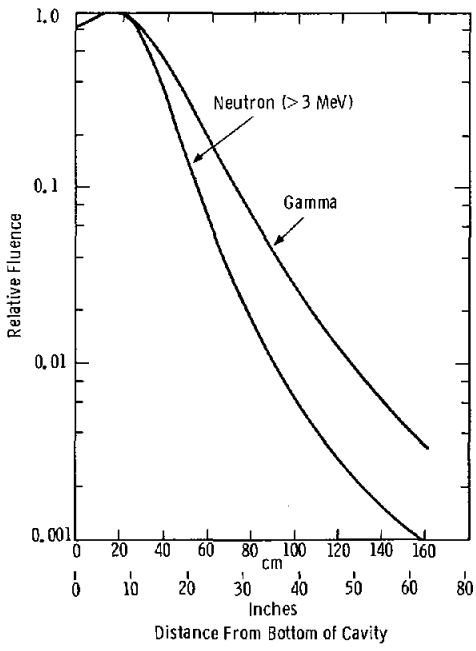


Figure 28. Relative Fluence at Cavity Centerline

Gamma Fluence

Free-field cavity gamma dose is shown in Figs. 29 and 30. Measurements were made using cobalt glass inside a boron ball. Relative gamma-fluence position data are also shown in Fig. 28. Steady-state gamma dose rate is 3300 rads (H_2O)/sec at 300 kW.

Background radiation levels vary, depending on core history before the experiment run, from about 1 to 8 rads/sec and higher. Because of this background, gamma doses are not predictable for steady-state power levels below about 3 kW.

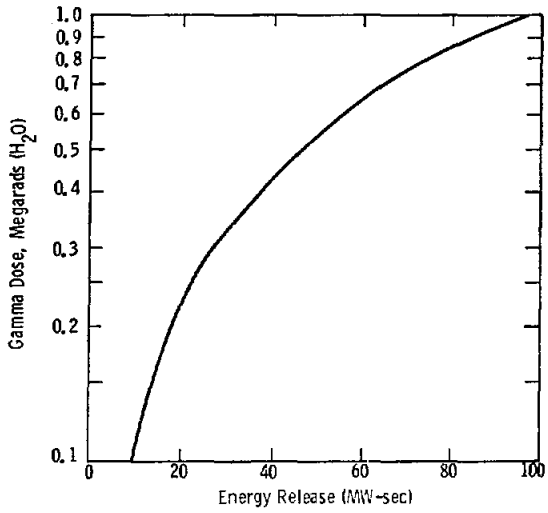


Figure 29. Cavity Gamma Dose Versus Pulse Energy Release

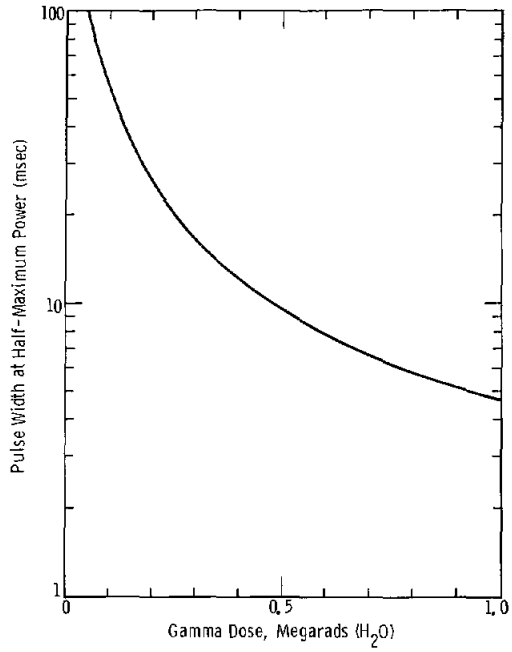


Figure 30. Pulse Width Versus Gamma Dose

Enhanced Gamma Pulses (Polyethylene-Cadmium Filter)

Gamma doses in excess of 1 megarad (H_2O) per pulse can be obtained using a polyethylene moderator and a cadmium filter to modify (thermalize) the bare-cavity neutron energy spectrum to produce additional gammas from the cadmium (n, γ) reaction. Figures 31 and 32 show the neutron energy spectrum modification for varying thicknesses of polyethylene annulus and an interior lining of 30 mils of cadmium, calculated using the DTF-IV code.[8] Figure 33 shows the gamma enhancement from a polyethylene-cadmium filter using the TLD-400 gamma dosimetry measurements from Ref. 10; these measurements were made using 30 kW-200 second power runs. The figure data were extrapolated from these steady-state measurements.

From these figures, it can be seen that the relative neutron/gamma ratio is markedly reduced using the filter technique.

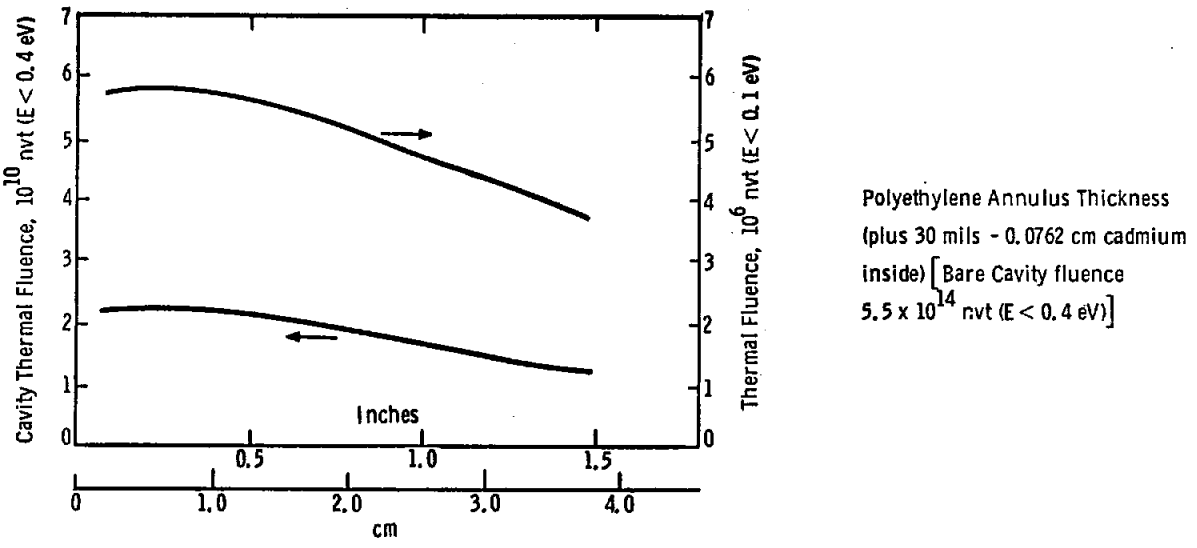


Figure 31. Maximum Pulse Thermal Fluence as a Function of a Variable Polyethylene Annulus Thickness and an Inner Cadmium Liner Thickness of 30 Mils (calculated using the DTF-IV Code, Ref 8)

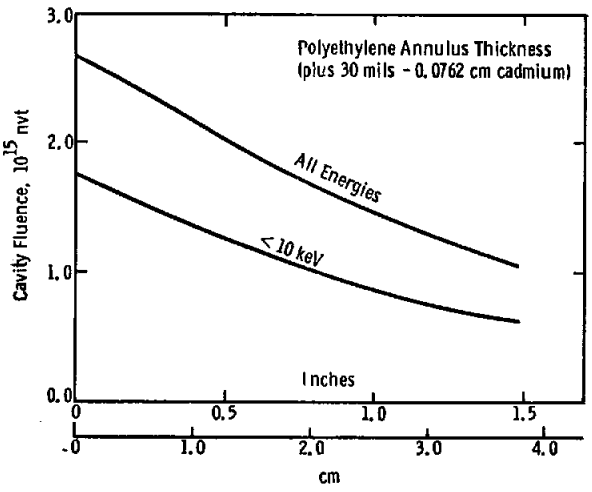


Figure 32. Maximum Pulse Centerline Fluence as a Function of a Variable Polyethylene Annulus Thickness and an Inner Cadmium Liner Thickness of 30 Mils (calculated using the DTF-IV Code, Ref 8)

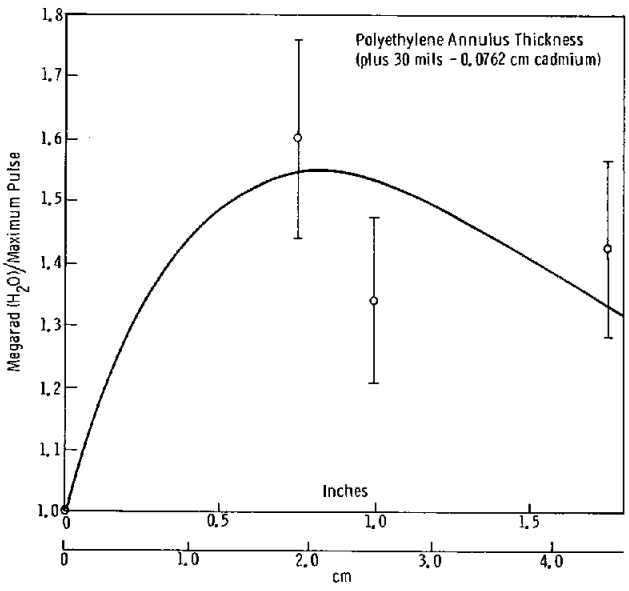


Figure 33. Maximum Pulse Enhanced Gamma Dose Data as a Function of a Variable Polyethylene Annulus Thickness and an Inner Cadmium Liner Thickness of 30 Mils. Data Were Extrapolated From 30 kW-200-Second Power Run Data

Equivalent Silicon Factor

Comparisons of damage from different neutron spectra are often based on equivalent damage to silicon by 1-MeV neutrons. This comparison is stated in terms of the 1-MeV equivalent silicon factor computed from

$$f = \frac{D}{\Phi C}$$

where

f = 1-MeV equivalent silicon factor

Φ = integral neutron fluence

C = conversion factor for 1-MeV neutrons, rads (silicon)/fluence

D = total silicon rads.

In general, f can have several distinct values for a given spectrum, depending on the definition of Φ, the integrated neutron fluence. In particular, there are two common definitions for Φ: (1) fluence over all neutron energies, and (2) fluence over neutron energies greater than 10 keV. The product of f times the proper Φ gives the fluence of 1-MeV neutrons required to produce equivalent silicon damage. f for the former is a measure of the damage per average neutron in a spectrum relative to a 1-MeV neutron. The latter is a convenient standard since in practice the fluence over neutron energies in excess of 10 keV is measured experimentally with a plutonium fission foil.

Based on the data in Table II and the numerical methods outlined in Ref. 11, the computed silicon factors are shown in Table V.

TABLE V

Silicon Equivalent Factors

	ACPR Bare Cavity	ACPR 2.54 cm Polyethylene	ACPR 0.0127 cm Cadmium
Fluence, E > 10 keV	0.78*	0.75	0.73
Fluence, E > 0	0.40	0.25	0.49

*Messenger quotes this value as 0.865.[12]

Neutron and Gamma Heating

Gamma and (selected) neutron heating of the elements per watt-sec are shown in Table VI. Gamma heating is based on assumed 1-MeV gamma rays. The specific heat at room temperature is assumed in the calculation of the adiabatic temperature rise of the elemental material.

TABLE VI

Neutron and Gamma Heating in the Elements

		Gamma (1 watt-sec)			Neutron (1 watt-sec)			
Z	Element	Dose Absorbed (rads)	Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Temp Rise Adiabatic ($^{o}C \times 10^{-6}$)	Dose Absorbed (rads)	Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Temp Rise Adiabatic ($^{o}C \times 10^{-6}$)	n/γ Ratio
1	Hydrogen	0.0222	0.0530	0.0155	0.289	0.691	0.203	13
2	Helium	0.0113	0.0270	0.0218				
3	Lithium	0.00986	0.0236	0.0278	0.0320	0.0765	0.09	3.25
4	Beryllium	0.0101	0.0241	0.0553	0.0120	0.0287	0.066	1.19
5	Boron	0.0105	0.0251	0.102				
6	Carbon	0.0115	0.0275	0.162	0.00439	0.0105	0.062	0.381
7	Nitrogen	0.0115	0.0275	0.110	0.00720	0.0172	0.069	0.626
8	Oxygen	0.0113	0.0270	0.123	0.00303	0.00724	0.033	0.268
9	Fluorine	0.0107	0.0256	0.129	0.00260	0.00621	0.032	0.0243
10	Neon	0.0112	0.0268	0.109				
11	Sodium	0.0108	0.0258	0.0881	0.00188	0.00449	0.0153	0.174
12	Magnesium	0.0112	0.0268	0.110	0.00124	0.00296	0.0122	0.111
13	Aluminum	0.0109	0.0261	0.121	0.00141	0.00337	0.0157	0.129
14	Silicon	0.0113	0.0270	0.161	0.000883	0.00211	0.0126	0.078
15	Phosphorus	0.0110	0.0263	0.145 white 0.164 red	0.00191	0.00456	0.0252 white 0.0285 red	0.174
16	Sulfur	0.0113	0.0270	0.154	0.00505	0.00120	0.0069	0.044
17	Chlorine	0.0108	0.0258	0.226	0.00933	0.00223	0.0196	0.086
18	Argon	0.0102	0.0244	0.197				
19	Potassium	0.0110	0.0263	0.146	0.00131	0.00313	0.0174	0.119
20	Calcium	0.0114	0.0272	0.174	0.000368	0.000880	0.0056	0.032
21	Scandium	0.0105	0.0251	0.189				
22	Titanium	0.0105	0.0251	0.201				
23	Vanadium	0.0103	0.0246	0.212				
24	Chromium	0.0105	0.0251	0.235				
25	Manganese	0.0105	0.0251	0.220				
26	Iron	0.0107	0.0256	0.242	0.000224	0.000535	0.005	0.021
27	Cobalt	0.0105	0.0251	0.230				
28	Nickel	0.0110	0.0263	0.248				
29	Copper	0.0105	0.0251	0.273	0.00129	0.00306	0.0333	0.122
30	Zinc	0.0106	0.0253	0.273				
31	Gallium	0.0103	0.0246	0.276				
32	Germanium	0.0102	0.0244	0.317				
33	Arsenic	0.0103	0.0246	0.313				
34	Selenium	0.0101	0.0241	0.314				
35	Bromine	0.0103	0.0246	0.351				
36	Krypton	0.0101	0.0241	0.408				
37	Rubidium	0.0102	0.0244	0.283				
38	Strontium	0.0103	0.0246	0.342				
39	Yttrium	0.0105	0.0251	0.369				
40	Zirconium	0.0105	0.0251	0.374				
41	Niobium	0.0106	0.0253	0.395				
42	Molybdenum	0.0107	0.0256	0.427				

TABLE VI (cont)

Z	Element	Gamma (1 watt-sec) Dose Absorbed (rads)	Gamma (1 watt-sec) Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Gamma (1 watt-sec) Temp Rise Adiabatic ($^{o}C \times 10^{-6}$)	Neutron (1 watt-sec) Dose Absorbed (rads)	Neutron (1 watt-sec) Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Neutron (1 watt-sec) Temp Rise Adiabatic ($^{o}C \times 10^{-6}$)	n/γ Ratio
43	Technetium	0.0106	0.0253	0.436				
44	Ruthenium	0.0105	0.0251	0.441				
45	Rhodium	0.0108	0.0258	0.443				
46	Palladium	0.0107	0.0256	0.438				
47	Silver	0.0110	0.0262	0.463				
48	Cadmium	0.0108	0.0258	0.465				
49	Indium	0.0109	0.0261	0.466				
50	Tin	0.0109	0.0261	0.511 α 0.492 β				
51	Antimony	0.0109	0.0261	0.533				
52	Tellurium	0.0107	0.0256	0.532				
53	Iodine	0.0111	0.0265	0.500				
54	Xenon	0.0110	0.0262	0.693				
55	Cesium	0.0112	0.0268	0.515				
56	Barium	0.0112	0.0268	0.582				
57	Lanthanum	0.0114	0.0272	0.579				
58	Cerium	0.0116	0.0277	0.565				
59	Praseodymium	0.0118	0.0282	0.613				
60	Neodymium	0.0119	0.0284	0.579				
61	Promethium	0.0119	0.0284	0.642				
62	Samarium	0.0121	0.0289	0.672				
63	Europium	0.0124	0.0296	0.703				
64	Gadolinium	0.0124	0.0296	0.538				
65	Terbium	0.0125	0.0299	0.684				
66	Dysprosium	0.0126	0.0301	0.727				
67	Holmium	0.0128	0.0306	0.778				
68	Erbium	0.0131	0.0313	0.781				
69	Thulium	0.0132	0.0315	0.825				
70	Ytterbium	0.0128	0.0306	0.884				
71	Lutetium	0.0137	0.0327	0.884				
72	Hafnium	0.0138	0.0330	0.943				
73	Tantalum	0.0140	0.0335	1.000				
74	Tungsten	0.0142	0.0339	1.069				
75	Rhenium	0.0145	0.0347	1.055				
76	Osmium	0.0144	0.0344	1.100				
77	Iridium	0.0146	0.0349	1.100				
78	Platinum	0.0148	0.0354	1.117				
79	Gold	0.0155	0.0370	1.201				
80	Mercury	0.0158	0.0378	1.142				
81	Thallium	0.0159	0.0380	1.238				
82	Lead	0.0162	0.0387	1.256				
83	Bismuth	0.0166	0.0397	1.341				
84	Polonium	0.0171	0.0409	1.363				
85	Astatine	0.0175	0.0418	-				
86	Radon	0.0172	0.0411	1.835				

TABLE VI (cont)

Z	Element	Gamma (1 watt-sec) Dose Absorbed (rads)	Gamma (1 watt-sec) Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Gamma (1 watt-sec) Temp Rise Adiabatic ($°C \times 10^{-6}$)	Neutron (1 watt-sec) Dose Absorbed (rads)	Neutron (1 watt-sec) Dose Absorbed $\left(\frac{cal}{gm} \times 10^{-6}\right)$	Neutron (1 watt-sec) Temp Rise Adiabatic ($°C \times 10^{-6}$)	n/γ Ratio
87	Francium	0.0177	0.0423	-				
88	Radium	0.0180	0.0430	1.493				
89	Actinium	0.0185	0.0442	-				
90	Thorium	0.0187	0.0447	1.649				
91	Protactinium	0.0194	0.0460	1.586				
92	Uranium	0.0200	0.0478	1.732				
93	Neptunium	0.0202	0.0483	2.226				
94	Plutonium	0.0209	0.0500	1.53				

The neutron dose data are based on the free-field neutron spectrum in Table III and are calculated using the methods of Ref. 11. The neutron/gamma dose ratio is also listed. Figure 34 shows the neutron/gamma dose ratio for the low-Z elements.

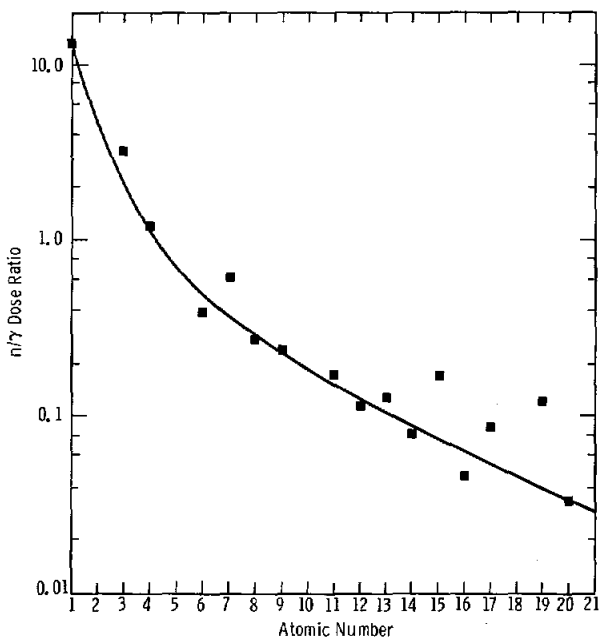


Figure 34. Neutron/Gamma Dose Ratio (Cavity, Free-Field) Versus Material Atomic Number

Table VII shows the energy density in UO_2 pellets, calculated with DTF-IV[8] as a function of ^{235}U enrichment and polyethylene annulus thickness. Certain of the table entries have been experimentally measured using a fission product inventory counting technique; calculated and measured values are in agreement to within ±15 percent.[13]

TABLE VII

Energy Deposited in UO_2 Pellet*
ACPR Pulse
(cal/gm/MW-sec)

Enrichment in ^{235}U (%)	Polyethylene Annulus Thickness (inches)						
	0.0	0.25	0.50	0.75	1.00	1.25	1.50
5	1.01	1.68	2.92	4.35	5.66	6.67	7.31
10	1.91	3.14	5.52	8.33	10.95	13.00	14.34
15	2.70	4.41	7.88	12.11	16.15	19.39	21.56
20	3.38	5.51	10.00	15.68	21.27	25.88	29.07
25	3.95	6.43	11.87	18.99	26.23	32.39	36.79

*Based on one-dimensional DTF-IV calculations (Ref. 8).

CHAPTER V

EXPERIMENT FACILITIES*

Central Irradiation Cavity

The dry central irradiation space is hexagonal to match the pattern of the fuel elements. The vertical length of the irradiation space is 0.30 meter and the inside dimension across the hexagonal flats is 0.23 meter. An experiment container 0.22 meter in diameter and 0.30 meter long can be vertically centered in the core. The lower stainless-steel reflector block, which is 0.13 meter thick, forms the bottom of the central cavity. The depth of the cavity can be altered by changing the thickness of this removable block.

Entrance to the central irradiation space can be gained through either the vertical access tube or the offset leg. The vertical access tube that forms the major portion of the Y extends from the hexagonal cavity to above the bridge--a permanent mounting platform cantilevered over the pool--that supports the upper end. The lower end of the curved offset tube branches from the vertical riser about 2.4 meters above the top of the core. The branching section angles to an offset of 1.6 meters and joins the lower end of the experiment storage chamber, which parallels the side of the tank and rises above its upper lip. The bends in the serpentine tube are gradual enough to allow an experiment 0.23 meter in diameter and 0.3 meter (to 0.46 meter maximum) to pass into the experiment region. Experiments to be actively monitored or environmentally controlled will have their attached cables or tubes fed through the offset access tube. Cabling or wires can terminate at poolside into electronic or diagnostic equipment. Tubing to carry cooling or heating to experiments can terminate in an appropriate supply at poolside. (Cable or tubing ~10.5 meters (35 feet) in length will suffice for experiments controlled or evaluated from poolside.)

The upper end of the offset tube terminates in the bottom portion of a stainless-steel post-irradiation chamber. The oblong chamber (0.8 meter by 0.35 meter cross section) is 2.3 meters high. The bottom of the storage section is 1.5 meters below the water surface. Lead shields are mounted on either side of the chamber 0.56 meter above the bottom of the section. When the workload requires it, experiments can be stored temporarily on each side and shielded by the water and lead until radioactive decay renders them low enough in activity to be removed. Because of its central location, experiment storage does not interfere with access to the opening of the loading tube.

In-Core Position

Experiments can be placed in any one of the 300 fuel-element core positions. An experiment can be mounted in a dummy fuel element or a special container, as long as it does not exceed the 3.7-cm diameter of a normal fuel element. The experiment is then handled as a fuel element.

*Extracted from Ref. 2.

A triangular section is provided in the core location for a sample whose diameter is greater than 3.7 cm. By removing three elements (core positions 207, 226, and 227, Fig. 6), plus their triangular support plate, specimens in a container up to 6.7 cm may be inserted in these positions. Although not mandatory, it is advantageous to duplicate the top triangular support plate as the top handling fixture for the special experiment container.

Experiment Cooling Area

An experiment may be transferred from the temporary cooling area to either of two concrete storage blocks near the pool. The blocks are 0.6 meter wide, 0.9 meter deep, and 1.8 meters long. Twelve openings, each 0.7 meter deep, are cut from steel pipe and imbedded in the concrete. The operator has available (4) 5-cm, (4) 10.2-cm, (2) 15.2-cm, and (2) 25.4-cm openings from which to choose. The 5-cm openings will accommodate either a fuel element or an experiment contained within a dummy fuel element.

Experiments are held in these storage cavities for long-term radioactive decay.

Pneumatic Transfer System

The flexo-rabbit (pneumatic transfer) system allows remote sample delivery for irradiation. The samples, 2.0 cm diameter by 5.84 cm long (maximum), are contained in molded polyethylene shuttle capsules; a capsule will travel the 12.2 meters from the core to the receiver in about 500 milliseconds. Travel time will vary according to gas pressure, sample weight, and direction of the capsule.

Three basic components make up the flexo-rabbit system: the irradiation end piece, the tubing system, and the control unit. The irradiation end piece, 4.58 meters long, is of aluminum throughout. Its lower end has the basic configuration of a fuel element and will fit directly into any fuel element position in the core grid plate, but normally is placed in core position 253. In this location the fast neutron flux ratio of cavity/rabbit is between 1.60 and 1.70, depending on control-rod positioning. Internal stops assure that the sample is positioned at the core center line. The upper end of the unit is joined to the flexible tubing system.

Two interconnected flexible tubes, a sample loader, and a dropout receiver make up the tubing system. The larger of the flexible tubes (3.3 cm I.D.) carries the shuttle capsule, while the smaller tube supplies and exhausts the driving gas. Normally the tubing system is about 12.2 meters long, but can be lengthened to extend the distance from the reactor area to the handling area.

The sample-loading end of the tubing system terminates in a quick-opening loader that is mounted to a lead brick so that the top can be opened with one hand. The loader also lends itself to operation by tongs or a remote manipulator.

The shuttle capsule normally drops into a large-volume box that has a shielding equivalent of 7.6 cm of lead. Approval by the Environmental Health group is required before the capsules can be removed from this box.

With the exception of loading the sample, selecting the exposure period, activating the start switch, and recovering the sample from the dropout unit, operation of the flexo-rabbit system is fully automatic. The automatic cycle may be interrupted at any time, returning the capsule, by operation of a switch on the control unit. Manual operation is similar to automatic operation except that the length of the irradiation period is controlled manually rather than by the timer.

Three signal outputs are available from the connectors at the rear of the control unit: (1) start of irradiation, (2) end of irradiation, and (3) arrival of sample at the receiver. These signals may be used to perform various functions.

Radiography Facility*

A stepped tube about 8 meters in length is used for the radiography facility. The tube is constructed of aluminum and stainless steel. The source end is 11 cm in diameter while the upper or exposure end is 25.4 cm in diameter. The lower end is secured by a fixture inserted into the lower grid plate. The tube stands nearly vertical, adjacent to the flat portion of the reactor core but about 5 cm from the nearest fuel elements. The upper portion is supported by a platform that rests on the upper edges of the pool. This platform also serves as a bridge upon which the experimenter gains access to the radiography equipment.

Two saddle tanks filled with D_2O enclose the lower end of the tube; addition of the tanks enhances the thermal fluence by about 34%. An arrangement of valves, traps, and hoses enables the operator to blow down and evacuate the central cavity. The traps prevent inadvertent flooding of the central cavity. During radiography, resolution is improved by continuously flushing the tube with helium gas, thereby lessening scattering. The helium is supplied from gas bottles through a regulator.

Collimators are normally added to the tube to provide a greater neutron source definition, thus enhancing the resolution obtainable for a given object. The 3.7-meter-long collimator is constructed from aluminum tubing 11 cm in diameter. The diameter-to-length ratio can be varied by adjusting the polyethylene, cadmium, and lead inserts in the lower holding fixture. Inserts are available that give the operator the option of varying the ratio from 65/1 to 500/1 (Table VIII).

A shield box is mounted over the top of the radiography tube. It functions as a radiation shield in addition to serving as blast protection for the drive systems of the regulating rods in the event of an explosive mishap. The box, which is 0.84 meter long, is open on the front toward the GIF cells.[4] The sides are 0.84 meter high and 0.79 meter deep, providing the radiographer with ample space in which to manipulate the experiment and his film cassettes. The sides of the shield consist of laminations of Plexiglass, cadmium sheet, and aluminum plate, while the top, which intercepts the direct beam, consists of a boral plate and three layers of borated polyethylene bricks. This shield attenuates a large proportion of the neutrons emerging from the beam tube. However, most of the gamma radiation easily penetrates the shield.

*An upgraded facility is expected in late 1974. Information on the new facility will be available from the authors.

A convenient facility for the radiographer, which is not classified as part of the reactor, is a photography dark room. This portable chamber is 1.2 meters on a side and 2.4 meters high. It contains a vacuum pump that permits film cassettes to be evacuated.

TABLE VIII

ACPR Radiography Facility Specifications

Collimator Ratio (L/D)	65/1	150/1	250/1	500/1
Neutron Beam Flux (n/cm^2-sec) at 300 Kilowatts	1.3×10^7	2.7×10^6	1.1×10^6	2.7×10^5
Neutron/Gamma Ratio (n/cm^2-mr)	1.6×10^6	1.3×10^6	1.3×10^6	9.3×10^5
Exposure Port Diameter (cm)	~15	26.4	26.4	26.4
Exposure Area (cm^2)	180	548	548	548
Cadmium Ratio	~8	> 15	> 15	> 15
Resolution for 2.54 cm Object to Film Detector Plane Distance (cm)	0.038	0.017	0.010	0.0051
Exposure Time for Single Coated R Film - Density 3 Background (minutes)	~4	~60	~90	~300

NOTES: 1. All values are for helium-filled tube.

2. Exposure time is for 0.0013 cm (1/2 mil) gadolinium converter screen.

3. Recent (unpublished) measurements indicate cadmium ratios of the order of 4-8.

Support Equipment

Requirements for conducting experiments are constantly changing, reflecting upon the support equipment that is maintained to accommodate experiments. As an illustration, a long-term steady-state run may require cooling; this necessitates supplying a flow of regulated air from a compressor system. A cryogenic experiment may require cooling with liquid nitrogen, or a vacuum system may be required on another experiment.

Spectrum altering, another capability, is performed by using cadmium sheets, poly rings, or boron-loaded buckets; a variety of metal or phenolic buckets is kept in stock to contain different experiments. A poolside hoist is used to lessen the physical effort of loading or unloading the experiment into the core.

Dummy fuel elements are kept on hand to house small in-core experiments.

Since most explosive experiments are conducted on the radiography tube, an explosive area, properly grounded and certified by the safety division, is near the radiography facility.

Contact the ACPR Reactor Supervisor with specific equipment requirements.

CHAPTER VI

OPERATING REGULATIONS

Facility Supervision

Supervision and operation of the ACPR reactor is a responsibility delegated by the Atomic Energy Commission through the President of Sandia Laboratories to the ACPR operations staff. The reactor can be operated only by qualified Sandia personnel, with a minimum crew consisting of a reactor supervisor, a reactor operator, and a health physicist or health physics monitor.

The reactor supervisor has overall responsibility for reactor operation and for conducting experiments in the facility. He has complete authority to discontinue or require modification of any operation that, in his opinion, endangers the safety of the reactor or of personnel and equipment within the facility. His approval of every experiment is required, both at the time the experiment plan is submitted and at the beginning of the experiment.

The reactor operator is directly responsible for operation of the reactor. His other duties include assisting the reactor supervisor and the health physicist in matters associated with the safety of the facility. He may, on his own authority, terminate any procedure that he considers dangerous.

The health physicist or health physics monitor is responsible for radiological and toxicological safety of personnel within the facility. He may also, on his own authority, stop any operation he considers dangerous. Specifically, his duties include:

1. Defining areas to which access is restricted because of radiological conditions.
2. Regulating and restricting radiation exposures to individuals. Personnel exposures will be limited to 100 mrem per week unless written authorization for larger doses is received from the user's responsible radiological safety official. (Non-Sandia organizations should address waiver authorization to: Supervisor, Environmental Health Operations Division, Sandia Laboratories, Albuquerque, New Mexico, 87115.)
3. Issuing special personal monitoring equipment.
4. Regulating the storage and handling of radioactive materials within the facility and the movement of such materials to areas outside the facility.

Upon arrival at the ACPR facility, experimenters will be briefed on applicable special regulations. Emergency procedures particularly will be outlined, and the various alarm systems explained.

All other aspects of personnel safety, such as the handling of explosive or fissionable materials, are the responsibility of the reactor supervisor, who will assure that the requirements of the pertinent Sandia Laboratories Instructions (SLI's) are satisfied.

Any person who violates or disregards the instructions of the reactor supervisor or health physicist in matters concerning the safety of personnel or equipment may be barred from further participation in ACPR operations by action of the ACPR committee.

Usage Procedure

Users of the ACPR facility must submit a final Experiment Plan 2 weeks before the experiment is to be performed. Since this plan serves as a reference for determining the inherent safety of the experiment, as well as establishing scheduling precedence, this period of time permits negotiation of modifications that may be necessary to satisfy safety or scheduling conflicts. It is emphasized that no experiment will be performed that in any way presents a hazard to the reactor or to operating personnel. Tear-Out Experiment Plan sheets are available at the end of this document for convenience. It is desired that the plan be "unclassified" if possible and reasonable; proper security classification documentation is required otherwise.

Experiments that could represent an unusual hazard to the reactor or personnel (e. g. , explosives, fissile materials, toxicological hazards, etc.) must be submitted for review and approval as much as 3 months in advance, depending upon the level of review required. Early contact and consultation with the ACPR Supervisor is essential.

CHAPTER VII

INFORMATION FOR NON-SANDIA USERS

General

The Annular Core Pulse Reactor is owned by the Atomic Energy Commission and is operated by Sandia Laboratories at Albuquerque, New Mexico. Its principal use is in a continuing program of fundamental and applied research in radiation effects. As such, the reactor is made available to Sandia Laboratories and to agencies and contractors of the AEC and the DOD.

Contract Procedure and Visitor Access

Non-Sandia agencies must sequentially follow the general schedule below:

1. Contractor schedules reactor time with the reactor supervisor. Telephone contact for this preliminary arrangement is encouraged: call (505) 264-8991.
2. Contractor contacts the Technical Projects Branch, Special Programs Division, USAEC-ALO, Albuquerque, New Mexico, 87115, submitting a formal request for reactor services, specifying dates and estimated time required.
3. After receipt of approval from Sandia, AEC negotiates the contract with, and formally assigns reactor services to, the contractor.

It is strongly suggested that the user make a preliminary visit to the facility to gain first-hand information on experiment setup, instrumentation, and access. During this visit, tentative schedules can be established and other preliminary arrangements completed. Once a tentative schedule has been established, contract negotiations with the AEC's Albuquerque Operations Office (ALO) should begin. It is emphasized that visitors and users should make arrangements for their visit and access at their earliest convenience to avoid scheduling difficulties and security clearance problems. Either DOD-Secret or AEC-Q clearances are required for access to the ACPR facility. All security arrangements should be completed at least 2 working days before the planned visit to the facility. Without such arrangements, access cannot be assured.

Notification of the signing of a contract between the user and ALO must be received by the reactor supervisor 5 working days before the initial experiment setup. Scheduled reactor time is not considered confirmed until the reactor supervisor is notified of the existence of a contract.

Schedule

Every effort will be made to provide the scheduled time requested. Sandia Laboratories cannot guarantee exclusive use of the reactor unless the nature of the experiment prevents usage by other groups because of the lack of available space or the peculiarities of the services desired

(e. g. , pulse size); it is necessary for users to specifically state in their experiment plan whether their use is such as to preclude sharing the reactor. If the reactor is shared, the hourly charge is pro-rated among all users. In addition, but only under unusual circumstances, Sandia Laboratories' programs may preempt contractor schedules with little advance notice.

Staff Support

The primary service provided by Sandia for the experimenter/user is a nuclear radiation environment from the reactor. The Sandia technical staff, which is competent in all phases of radiation effects, is available for consulting services only on an occasional and limited basis unless special contractual arrangements are made. If experiments involve radioactive or toxic substances, a Sandia health physicist is assigned the responsibility of regulating personnel exposures and insuring that proper handling procedures are employed.

The supervisors and operators of the reactor will exercise their best efforts, in conformance with the ACPR Operating Procedures, to provide the desired environment.

Miscellaneous Services

Dosimetry -- Dosimetry data can be provided by the Sandia Laboratories Nuclear Counting Laboratory. Standard foil techniques are used for neutron measurements; glass-rod and TLD dosimetry for gamma measurements. The experimenter may make his own measurements if he prefers.

Depending on the Counting Laboratory work schedule, some data may be available immediately (i. e. , in a few hours to 1 day); in any case, after the experiments, all dosimetry and personnel exposure data will be forwarded by mail.

Computational Facilities -- Limited calculation facilities are available at the reactor site. The Sandia Laboratories computational laboratory may be made available on a limited basis by special prearrangement.

Shop Facilities -- Light machine-shop facilities are available at the reactor site.

Experiment Preparation -- Preparation and setup areas are available.

Photographic Equipment and Materials -- Limited photographic equipment is available. Oscilloscope cameras and film are available on an advance-notice basis.

Charges

At the date of publication of this document, charges for use of the ACPR facility were:

1. Exclusive use of the reactor is charged at $122 per hour.
2. Overtime (outside normal working hours) is charged at $122 an hour, but is available only if previously scheduled or if required by unforeseen conditions.

3. Charges for reactor operations benefitting two or more users are prorated among all users at the rate of $122 per hour.

4. There is no charge for nonreactor time (setup and preparation) as long as such work does not interfere with reactor operations.

5. Staff-member time charges average $26 per hour, and such time is available only if prearranged by contract.

6. Standard dosimetry charges are:

Boron (^{10}Bo) ball - Pu, Np, U fission foils	$8/ball
Sulfur foils (^{32}S), Nickel foils (^{58}Ni)	$2/foil
Gold foils (^{197}Au), 1 bare and 1 cadmium-covered	$8/set
Gamma dosimeters	$2/dosimeter

All users are required to acknowledge charges incurred at the ACPR facility before their departure. Charge rates for other services can be arranged as required. All rates are subject to change without advance notice.

Miscellaneous

Accommodation and Transportation -- There are several motels, hotels, and restraurants convenient to Kirtland Air Force Base East, as well as military accommodations on the base. The remote location of the ACPR facility makes it necessary for experimenters to provide their own transportation.

Shipping Instructions -- Outside agencies must make all their own arrangements for shipping equipment to Sandia Laboratories, including provisions for drayage and other local requirements. Address shipments to ACPR Reactor Supervisor, Sandia Laboratories, Kirtland Air Force Base East, Albuquerque, New Mexico, 87115.

Additional Information -- Information not included in this report may be obtained by contacting the ACPR supervisor; call (505) 264-8991.

CHAPTER VIII

SUMMARY

The ACPR facility provides a transient or steady-state radiation environment readily applicable to radiation-effects experiments. The facility is available to agencies of the Department of Defense and to private enterprises having AEC or DOD contracts requiring the use of the reactor. The reactor is available on the basis of noninterference with Sandia Laboratories programs.

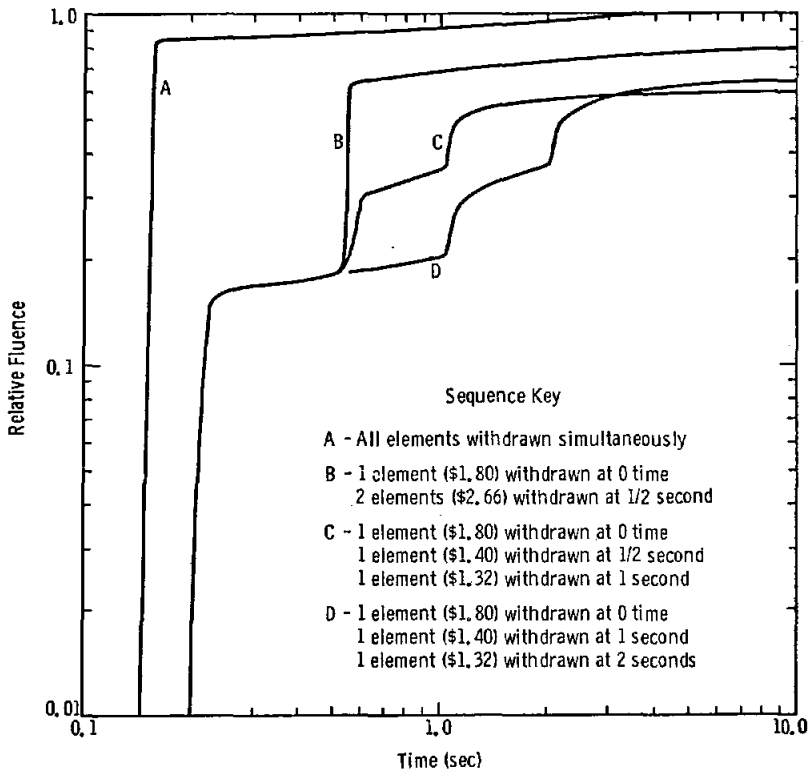
It is strongly suggested that the user make a preliminary visit to the facility to gain first-hand knowledge regarding the applicability of his experiment to the reactor. During this visit tentative schedules can be established and other preliminary arrangements can be completed.

Security clearances are required for access to the reactor site.

APPENDIX

SHAPED-PULSE OPERATION

Recent experimenter requirements for a pre-heat capability followed by a pulse environment have led to the "rediscovery" of an available, but never used, pulse-rod programmed insertion technique. The pulse rods are withdrawn according to a pre-programmed insertion timer, with the insertion times variable over an extended time range. Typical results of such an operation are shown in the following figure.



Relative Fluence for Different Shaped Pulse Operations

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5100 J. K. Galt
5112 E. P. Eernisse
5112 C. E. Barnes
5112 W. Beezhold
5112 K. L. Brower
5112 L. V. Hansen
5112 H. J. Stein
5113 D. G. Schueler
5155 R. D. Nasby
5200 E. H. Beckner
Attn: 5210 J. B. Gerardo
5240 G. Yonas
5250 H. D. Sivinski
5220 J. V. Walker
Attn: 5222 R. L. Coats
5223 J. H. Renken
5226 L. D. Posey
5220A P. B. Tollefsrud
5221 J. A. Reuscher
5221 L. L. Bonzon
5221 J. C. Conant
5221 R. S. Domingues
5221 B. F. Estes
5221 V. E. James
5221 R. D. Meyer
5221 F. M. Morris
5221 J. S. Philbin
5221 J. A. Snyder
5221 F. V. Thome (200)
5222 F. Gonzalez
5222 J. A. Horak
5222 W. H. McAtee
5222 J. B. Rivard
5222 D. J. Sasmor
5222 T. R. Schmidt
5226 W. H. Buckalew
5226 S. R. Dolce
5226 D. W. Dugan
5226 H. L. Kefauver
5226 D. A. McArthur
5226 G. H. Miller
5226 J. F. Schulze
5226 H. N. Woodall
5243 J. E. Powell
5251 C. A. Trauth
5252 K. F. Lindell
5252 M. C. Reynolds
5600 A. Y. Pope
5628 I. Auerbach
5700 J. H. Scott
5723 A. C. Wilken
5800 L. M. Berry
5810 R. G. Kepler
5811 L. A. Harrah
5811 E. A. Salazar
5813 D. R. Anderson
5814 R. C. Hughes
5822 B. T. Kenna
5822 P. E. Harrison
5830 M. J. Davis
5831 N. J. Magnani
5832 R. W. Rohde
5833 J. L. Ledman
5833 R. E. Fisher
8300 B. F. Murphey
8310 R. H. Meinken
8330 G. W. Anderson, Jr.
8340 J. L. Wirth
8344 L. W. Dahlke
9324 D. K. Overmier
9350 F. W. Neilson
9351 D. W. Ballard
9351 F. A. Hasenkamp
9351 R. W. Mottern
9352 O. J. Burchett
9352 R. H. Yoshimura
9513 W. W. Westman
9513 R. E. White
9513 L. E. Horner
9513 W. W. Kuhn
9514 R. R. Evans
9514 J. A. Teresi
9515 R. R. Balthaser
9515 C. F. Schroeder
9515 R. M. Edgar
9515 C. E. Muchow
9523 A. C. Littleford
9523 S. L. Love
9523 L. W. Peterson
9524-1 E. H. Morris (Pantex)
9655 D. N. Cox
8266 E. A. Aas (2)
3141 L. S. Ostrander (5)
3151 W. F. Carstens (3)
For AEC/TIC (Unlimited Release)

ANNULAR CORE PULSE REACTOR

EXPERIMENT PLAN

To: ACPR Control
Div. 5221
Ext. 264-8991

From: _____ Project Leader

_____ Org. _____ Case No.

_____ Ext. _____ Part No.

Title of Experiment: _____

Unusual Requirement: _____

_____

Number of pulses desired and exposure level: _____

_____

Date experiment to be irradiated: _____ Security Classification: _____

Dimensions, maximum overall: _____

Dosimetry Required: (_____) Neutron (_____) Gamma

Composition of sample (major elements): _____ Mass: _____

Solid ( ) Liquid ( )

Is Liquid: Completely contained? ( ) Yes ( ) No

Unstable in any way? ( ) Yes ( ) No

Approx. melting point: _____ °C

* Is the test item or its associated test gear a safety hazard? i. e., Does test item contain toxic materials, fissile materials, explosive material or large energy storage devices, or highly flammable material? (___) Yes. (___) No. If answer is Yes, complete other side.

		DOSIMETRY DATA		
Date	Requested NVT	Run	Neut.	Gamma

Experiment Approval:

Operations _____ Health Physics _____ Committee _____

NOTE: Must be answered

TEST ITEM CONTAINS:

1. Highly flammable material (___) Yes (___) No _____ Material
2. Toxic material (___) Yes (___) No _____ Material
3. Fissile material _____ U235 _____ Pu239 _____ U233 _____ number of grams
4. Internal electrical power sources

   Specify: (voltage and capacitances)

   _____
5. High internal pressure

   Specify: _____ Pressure _____ Volume _____ Gas
6. Explosive Device name and number _____

   A. Type:

Purpose	Explosive	Grams	Remarks
Primer or IP			
Booster			
Base charge			
Pyrotechnic			
Propellant			
Total charge			

   B. Bridge-wire information:

   Does test item contain a bridge-wire? (___) Yes (___) No

   Is bridge-wire shorted and grounded to case? (___) Yes (___) No

   Nominal bridge-wire resistance: _____ ohms

   Current in amperes _____ No fire _____ All fire

   Power in watts _____ No fire _____ All fire

   C. Initiation sensitivity:

   _____ Static _____ Spark _____ Shock

   D. Quantities: Building 6588 ACPR* _____

   Number to be exposed together _____ (Total Charge: _____)
7. Comment _____
8. Requester Signature _____ Org. _____ Date _____

Approvals:

_____ 9351

_____ 9542

_____ 5221

_____ Requestor Project Leader

_____ Appropriate Reactor Committee

*Usually Bldg. 6588 ACPR will only be used for nondestructive testing and short time storage of radioactive test items.

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_____

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Unstable in any way? ( ) Yes ( ) No

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		DOSIMETRY DATA		
Date	Requested NVT	Run	Neut.	Gamma

Experiment Approval:

Operations _____ Health Physics _____ Committee _____

*NOTE: Must be answered

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   Specify: (voltage and capacitances)

   _____
5. High internal pressure

   Specify: _____ Pressure _____ Volume _____ Gas
6. Explosive Device name and number _____

   A. Type:

Purpose	Explosive	Grams	Remarks
Primer or IP			
Booster			
Base charge			
Pyrotechnic			
Propellant			
Total charge			

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   D. Quantities: Building 6588 ACPR* _____

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Div. 5221
Ext. 264-8991

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_____ Ext. _____ Part No.

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Unusual Requirement: _____

_____

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		DOSIMETRY DATA		
Date	Requested NVT	Run	Neut.	Gamma

Experiment Approval:

Operations _____ Health Physics _____ Committee _____

*NOTE: Must be answered

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3. Fissile material _____ U235 _____ Pu239 _____ U233 _____ number of grams
4. Internal electrical power sources

   Specify: (voltage and capacitances)

   _____
5. High internal pressure

   Specify: _____ Pressure _____ Volume _____ Gas
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   C. Initiation sensitivity:

      _____ Static _____ Spark _____ Shock

   D. Quantities: Building 6588 ACPR* _____

      Number to be exposed together _____ (Total Charge: _____)
7. Comment _____
8. Requester Signature _____ Org. _____ Date _____

Approvals:

_____ 9351

_____ 9542

_____ 5221

_____ Requestor Project Leader

_____ Appropriate Reactor Committee

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